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Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

APPROVED BY: Jay H. Laue
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STG Vice President
Aerospace Systems

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STG Vice President
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SRS
TECHNOLOGIES

SYSTEMS TECHNOLOGY GROUP

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**Volume III - Appendix B
Task 2 Report
ECLSS Evolution: Intermodule Ventilation Study**

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ABSTRACT

This task report contains two distinct sections. First is the draft report of the work which was performed in Part 1. The report is entitled "An Investigation of the Growth of Intermodule Ventilation Systems and Water Distribution Systems to Accommodate the Addition of a Hab and a Lab Module with Nodes to the Assembly Complete SSF Configuration." The second section is a report and complete set of presentation charts showing the results of the Part 2 Intermodule Ventilation studies.

1. A Report on the Intermodule Ventilation Work Performed During Part 1



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DRAFT

SRS/STG TN91-02

**AN INVESTIGATION OF THE GROWTH OF INTERMODULE
VENTILATION SYSTEMS AND WATER DISTRIBUTION SYSTEMS TO
ACCOMMODATE THE ADDITION OF A HAB AND A LAB MODULE WITH
NODES TO THE ASSEMBLY COMPLETE SSF CONFIGURATION**

OCTOBER 24, 1990

ADVANCED LIFE SUPPORT STUDY (CONTRACT NAS8-38781)

Approved by:

Jay H. Laue
Director
Aerospace Systems Directorate

FOREWORD

This Technical Note (TN) serves as an interim documentation of the objectives, approach, background guidelines/assumptions, and results/conclusions of a study performed in response to an action given to SRS Technologies by the NASA COTR, Mr. Paul O. Wieland/ED62. The activity was performed under the "Advanced Life Support Study" (Contract NAS8-38781). The SRS project Manager is Mr. Edward E. Montgomery. Mr. Joseph C. Cody led the analysis effort assisted by Mr. David E. Marty who developed and executed supporting computer models. Other contributors included:

Jim Pearson

Deborah Kromis

John McDonald.

1.0 INTRODUCTION

PROBLEM STATEMENT: The purpose of this investigation is to determine if the intermodule ventilation (IMV) systems, and water distribution systems of Space Station Freedom (SSF) modules and nodes should be connected as they are interfaced with those already in operation.

2.0 BACKGROUND INFORMATION

The pressurized elements of the current Space Station Freedom (SSF) Assembly Complete (AC) configuration contain US Hab 1, US Lab 1, Nodes 1, 2, 3, 4, and air locks as shown in Figure 1. Shown also is the post-turbo atmosphere revitalization systems locations. The water management systems are shown in Figure 2. In addition to the modules shown in Figures 1 and 2, other pressurized modules include Pressurized Logistics Modules (PLOG), Air Lock (AL), Hyperbaric Airlock (HAL), Japanese Experiment Module (JEM), and European Space Agency (ESA) Columbus Module. This configuration is shown in Figure 3.

The SSF Growth Configuration including US Hab 2, US Lab 2, and Nodes 5, 6, 7 and 8 is shown schematically in Figure 4.

3.0 ANALYSIS APPROACH

Schematics of the Assembly Complete Configuration were developed including the attached modules (Figure 3). The intermodule flow configuration, representing the series/parallel flow concept was added as shown in Figure 5. A simplified computer program was developed to determine the steady state partial pressure of CO₂ (P_{CO2}) in each pressurized compartment as a function of ventilation flow configurations (Isolated and Integrated IMV), CO₂ removal system location, and crew size and location. The merits of providing water transfer across the connecting interfaces is also addressed.

4.0 GROUND RULES AND ASSUMPTIONS

- 1) The control of atmospheric CO₂, O₂ and trace contaminants will be performed by ECLSS units located in the HAB and LAB modules with a redundant Atmosphere Revitalization (AR) system in NODE 3 for the AC configuration.
- 2) The intermodule air system shall accommodate isolation of pressurized elements and provide air into the crew in non-isolated elements. No intermodule air transfer is assumed through isolated modules or nodes.
- 3) The additional Hab and Lab modules will contain ECLSS to control CO₂, O₂ and trace contaminants. A redundant atmosphere revitalization system will be located in one of the nodes. Each module will contain a Water Management System.
- 4) The addition of modules and nodes will be consistent with 2) above.

5) The series/parallels ventilation concept is assumed for the AC configuration.

The CO₂ model was run for several scenarios of crew location, flowrates, and ventilation flow configurations. Several scenarios describing potential attachment sequences and locations for a redundant AR system were investigated.

5.0 ANALYSIS RESULTS

Several IMV approaches were investigated such as all parallel, series in the outer modules/parallel in the center hab and lab modules. The parallel flow IMV system for the attached modules and nodes was judged to be the best approach because it can be integrated with the Assembly Complete (AC) configuration without impacting the AC IMV series/parallel design. The approach is also compatible with the sequential attachment of the additional Hab, Lab, and nodes as SSF evolves into the growth configuration shown in Figure 5.

The capability of the IMV to maintain acceptable CO₂ concentrations with the added modules isolated was investigated. This configuration is shown in Figure 6. The partial pressure of CO₂ buildup in the isolated volumes as a function of crew occupancy is shown in Figure 7; with a single AR unit only four crew members can occupy this volume without exceeding 3 mmHg partial pressure of CO₂. With both AR units operating about eight crew members can occupy the volume without exceeding 3 mmHg CO₂ partial pressure. For this scenario an additional AR unit must be provided in the Hab 2 module to meet redundancy requirements. Consequently, isolating the ventilation system penalizes the station in terms of crew operational flexibility and the requirement of an additional AR unit.

The capability of the connected series/parallel flow IMV system to control the CO₂ concentration for various crew distributions is shown in Figures 8, 9, and 10. The worst case is shown in Figure 10 for Log 2 and Columbus. The CO₂ concentration is slightly higher than the allowable operational limit in these modules. The simulation of the CO₂ removal unit, in the analysis, may not exactly represent the performance of the flight unit. It was not the intent of this investigation to size the CO₂ removal unit. Although the simulation may be in error, the distribution trends should be representative.

In addition to connecting the IMV, the water circuits should also be integrated. In the disconnected mode, condensate and other water collected in LAB 2 and HAB 2 can not be transferred to water management systems in the other modules. Depending on crew activity and location, water usage may not meet water requirements in each module. An option for integrating the urine vent is shown in Figure 11.

6.0 CONCLUSIONS

The IMV systems of the AC configuration and attached LAB and HAB modules and Nodes should be innerconnected. The H₂O circuits should also be innerconnected. Innerconnecting the air and water system provides flexibility of operation and safety comparable to the AC configuration. The IMV scars for the AC configuration can be reduced by providing the IMV fans in the nodes to be attached to the AC configuration (Nodes 5, 6, 7 and 8 in Figure 5). This requires only valves and ducts to be provided in the AC nodes. The AC node interfaces should also be scarred to provide for water transfer across these interfaces. Penalties for not connecting the IMV and water circuits include an additional AR unit, possible increased water storage requirements, and considerable reduction in crew flexibility.

LIST OF FIGURES

NUMBER	TITLE
1	Post-Turbo AR Subsystem Configuration
2	Post-Turbo WRM Subsystem Configuration
3	SSF Assembly Complete Configuration
4	SSF Growth Configuration
5	Interconnect Option for IMV
6	Hab and Lab IMV Isolated from AC Configuration
7	Isolated Lab 2 Module CO ₂ Partial Pressure
8	Crew Located in Hab 1 and Lab 1
9	Crew Located in Hab 1&2 and Lab 1&2
10	Crew Distributed
11	Inner Connect Option for UPA Vent

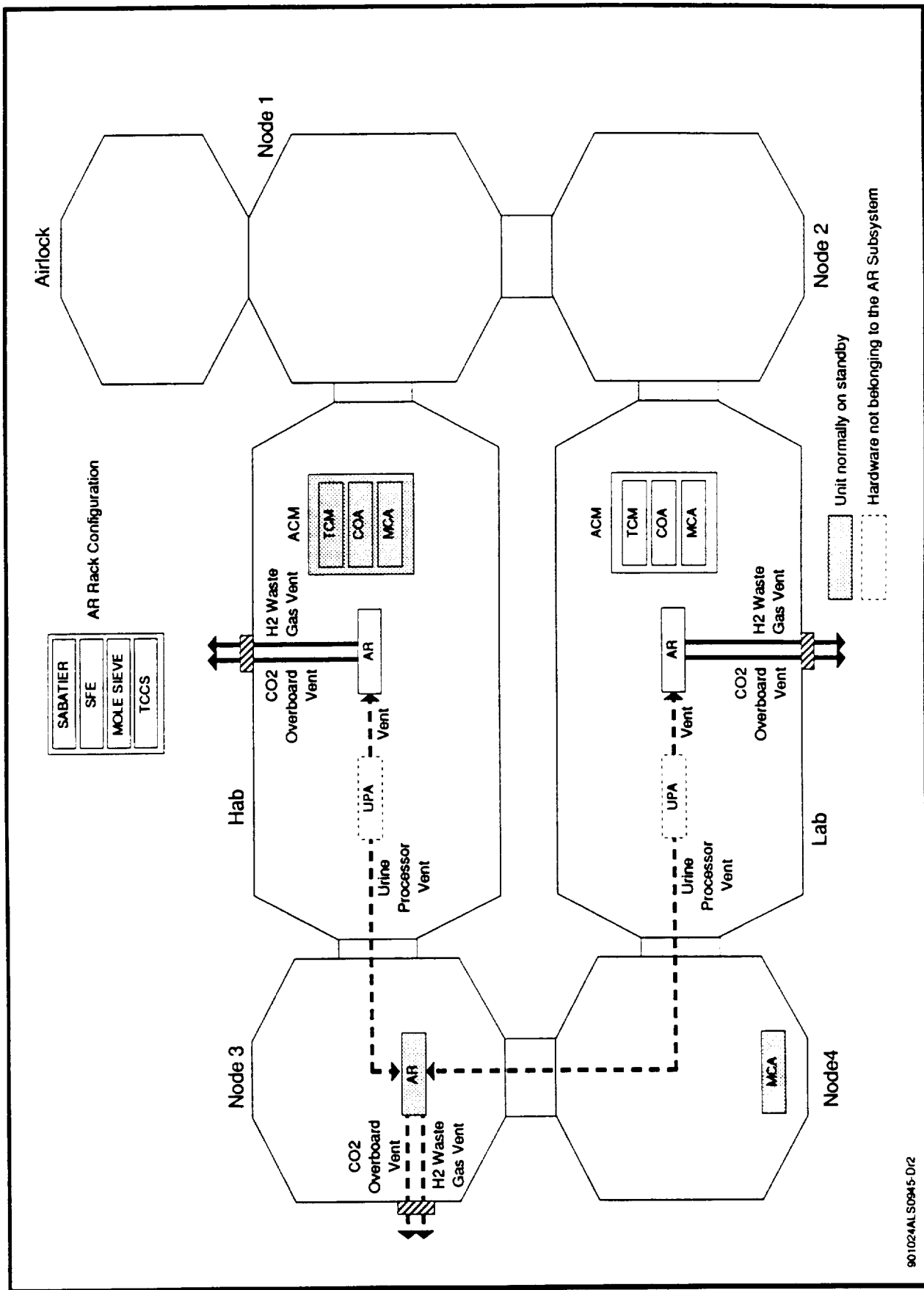


Figure 1 Post-Turbo AR Subsystem Configuration

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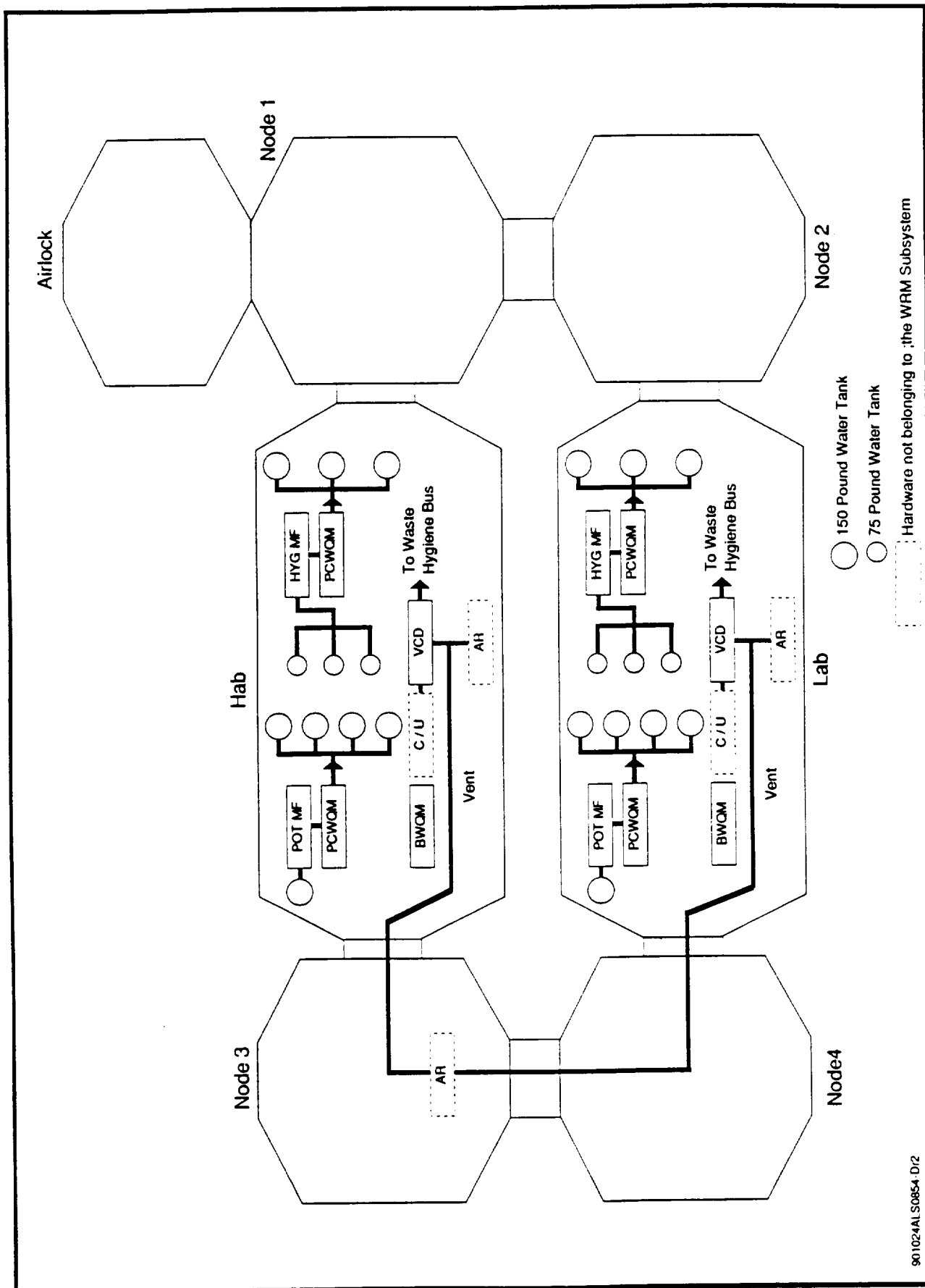


Figure 2 Post-Turbo WRM Subsystem Configuration

SSF AC Schematic

SSF AC Schematic

Symbol Legend

AR Air Revitalization Unit

Diagram Labels:

- HVP AIRLOCK VOL - 940 ft³
- US HAB 1 VOL - 6166 ft³
- US LAB 1 VOL - 6166 ft³
- AIRLOCK VOL - 725 ft³
- NODE 1 VOL - 2805 ft³
- NODE 2 VOL - 2805 ft³
- NODE 3 VOL - 2805 ft³
- NODE 4 VOL - 2805 ft³
- COLUMBUS VOL - 4081 ft³
- JEM VOL - 4081 ft³
- JEM LOG VOL - 1413 ft³
- US LOG 1 (Alternate Location) VOL - 2805 ft³
- US LOG 1 VOL - 2805 ft³

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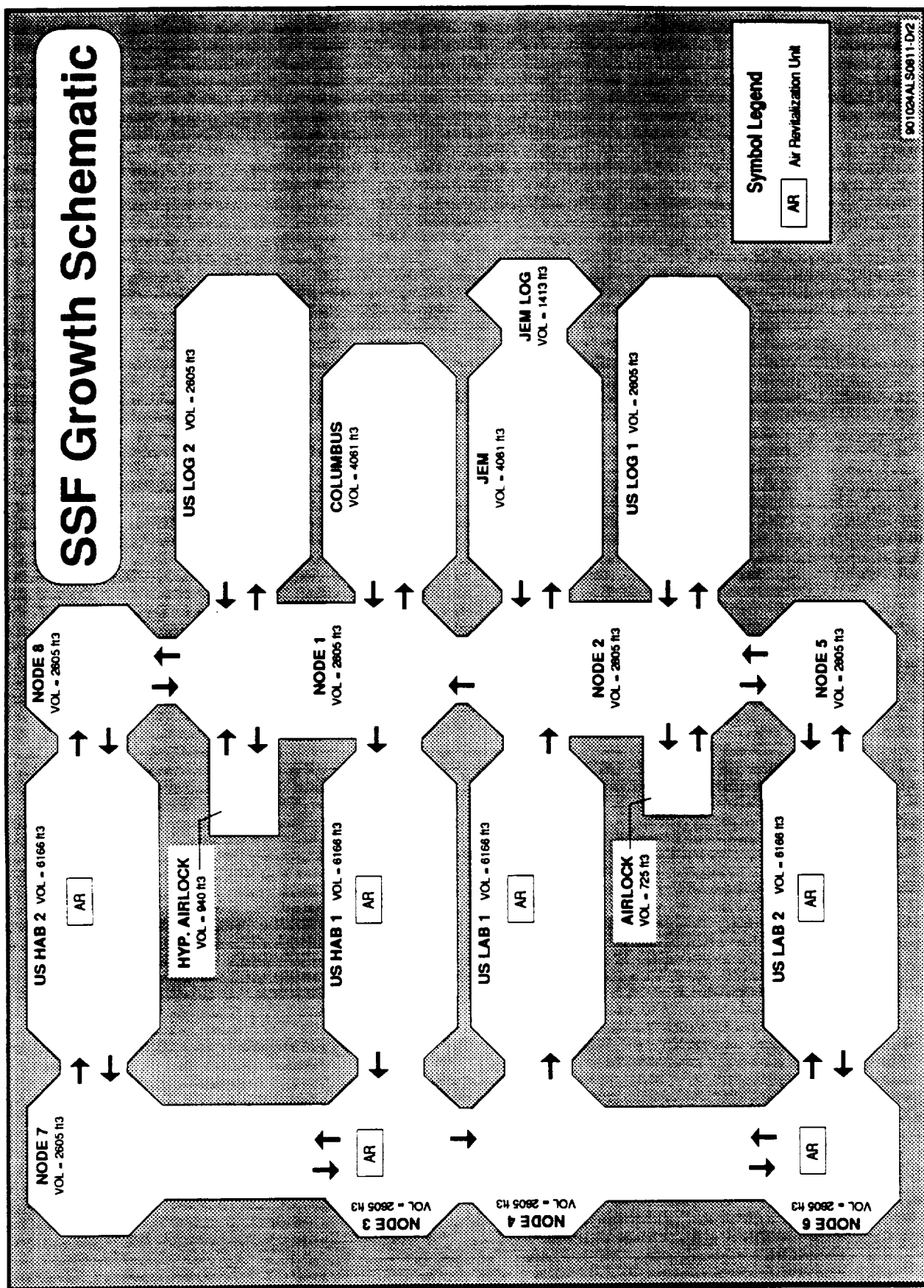


Figure 4 SSF with US HAB 2 and US LAB 2 Attached

SSF Growth Schematic

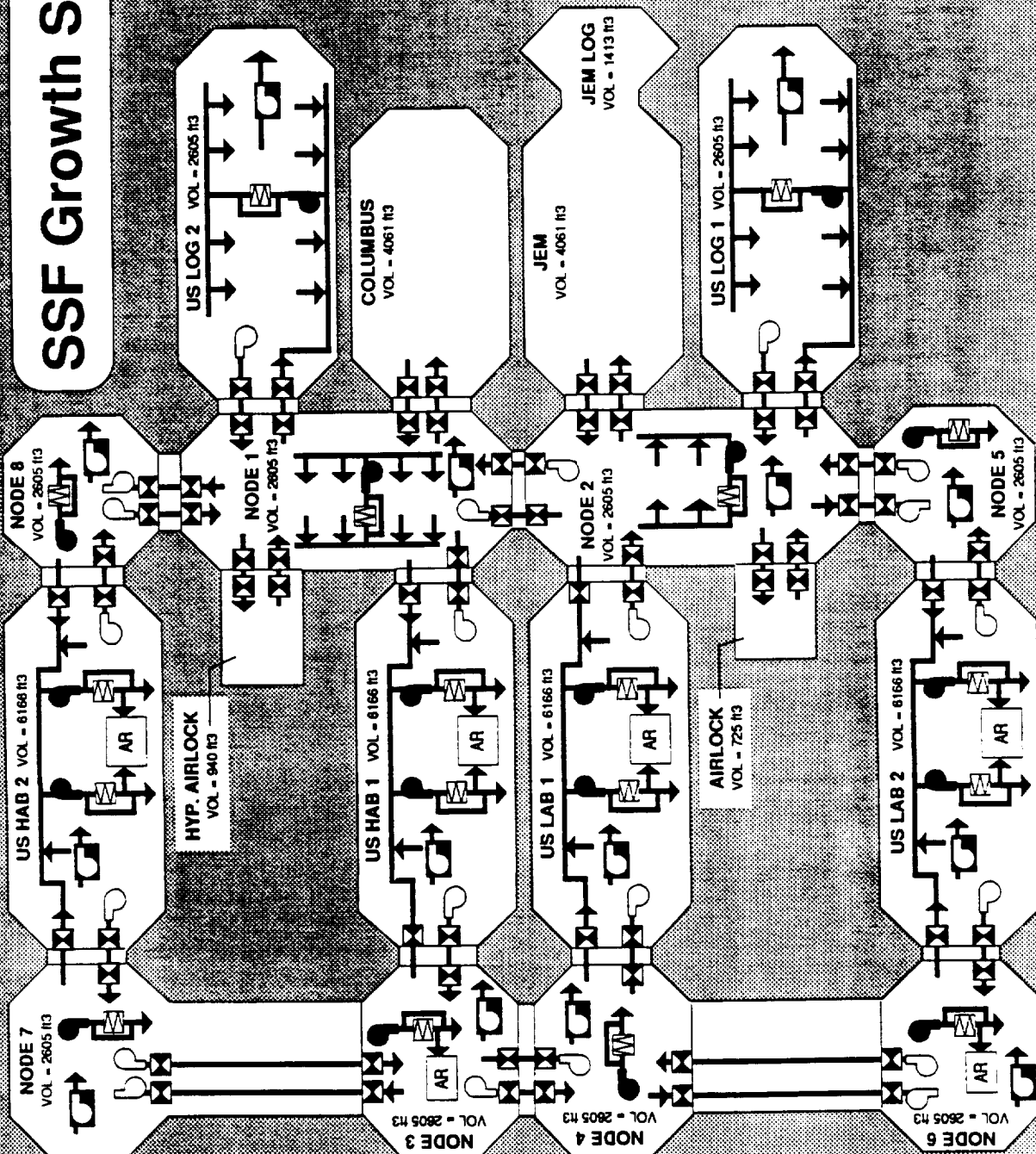


Figure 5 Innerconnect Option for IMV

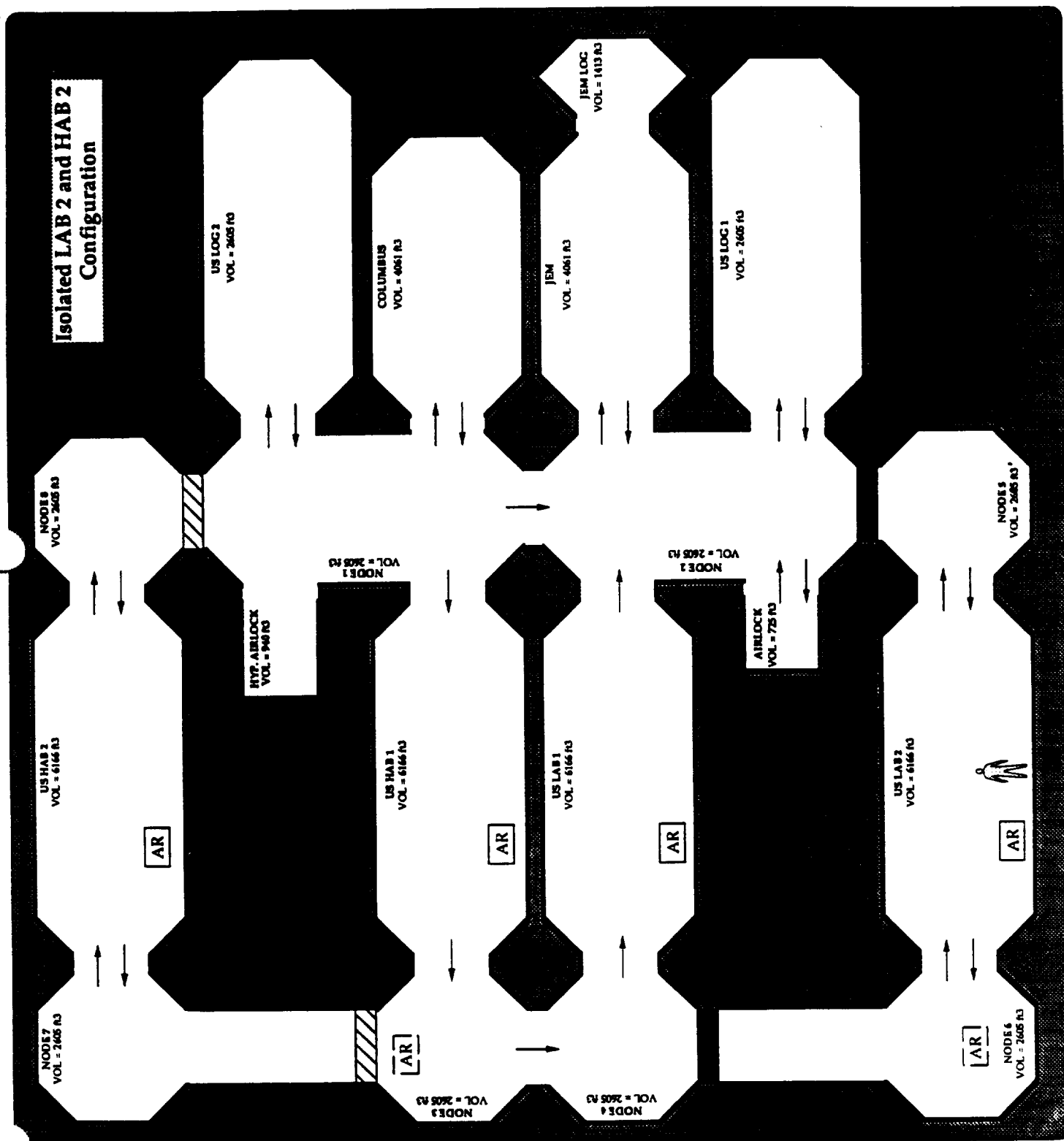
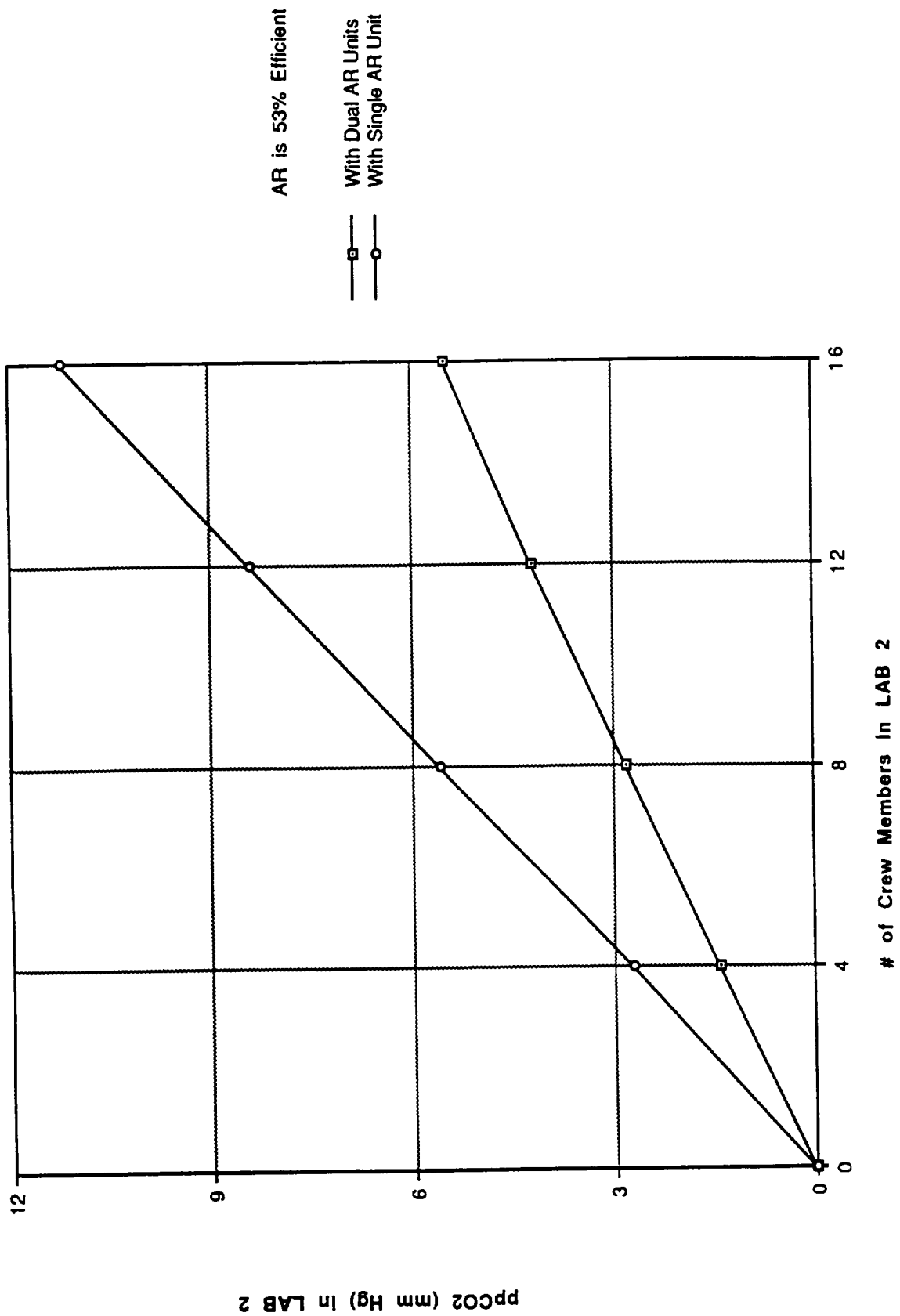


Figure 6 Hab and Lab IMV Isolated From AC Configuration

Figure 7 Isolated LAB 2 Module CO2 Partial Pressure



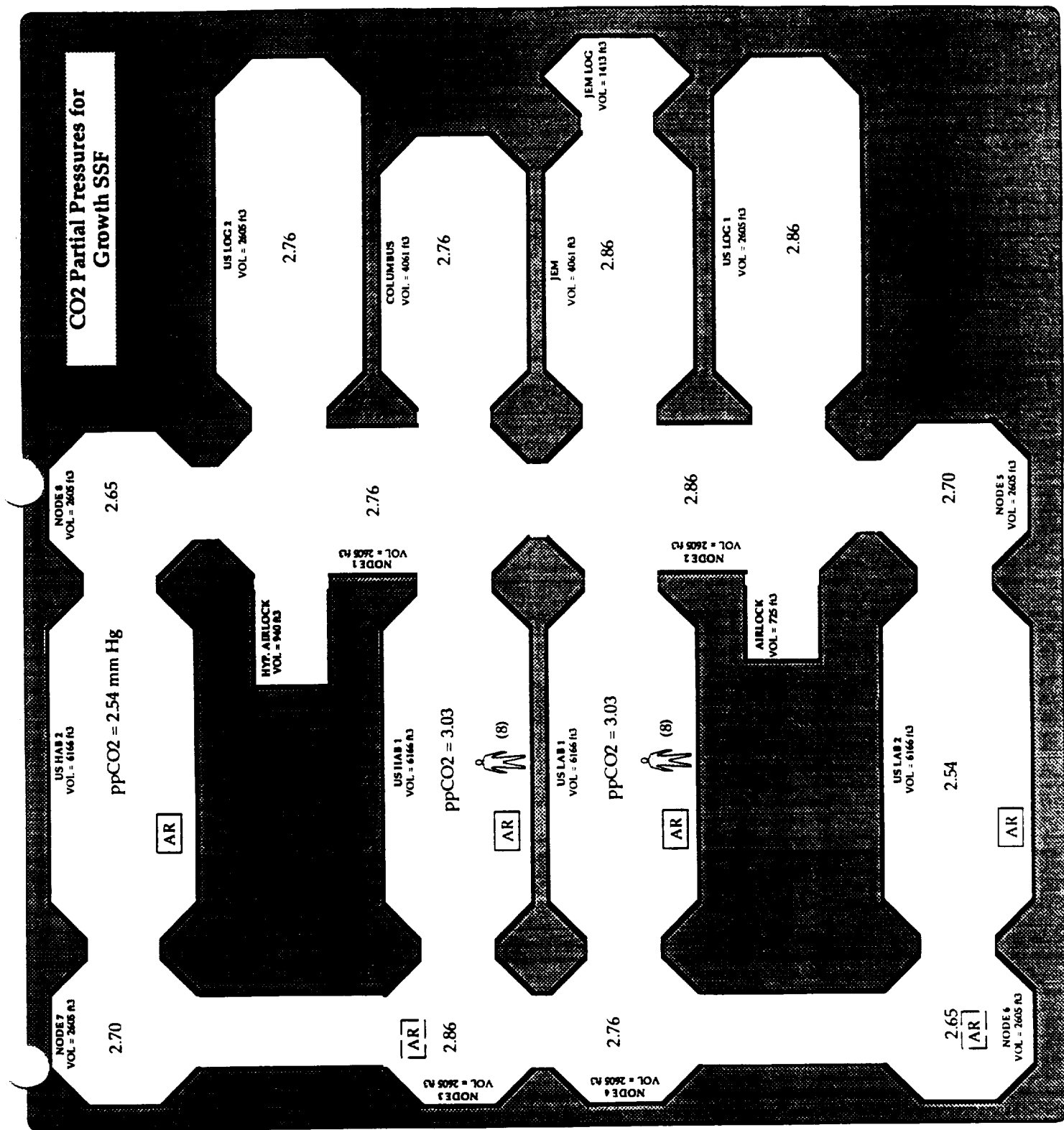


Figure 8 Crew Located in HAB 1 and LAB 1

CO2 Partial Pressures for SSF

IMV = 140 cfm
Series/Parallel

AR = Active Unit

AR = Backup Unit
(not active)

AR's 53% efficient

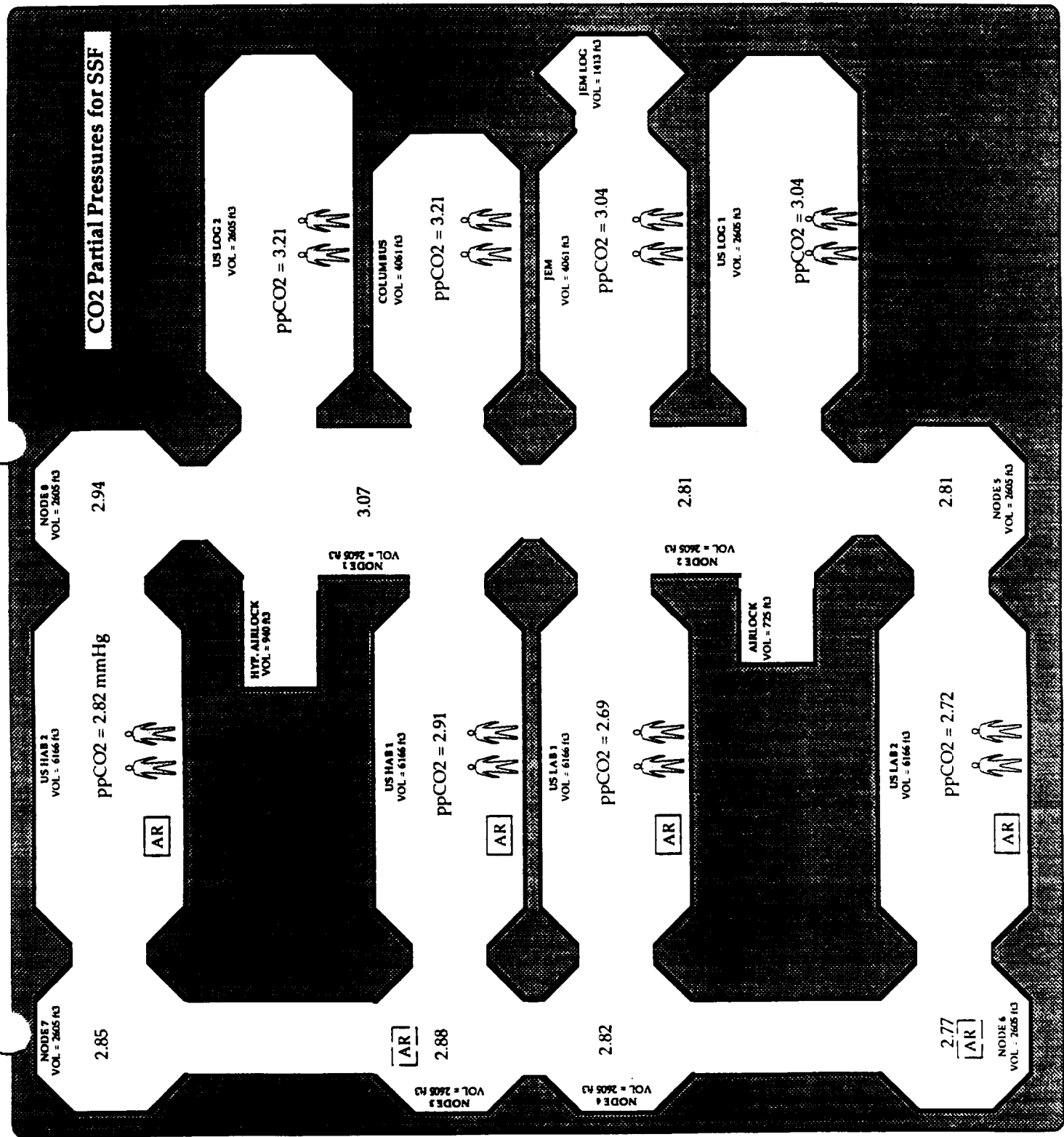
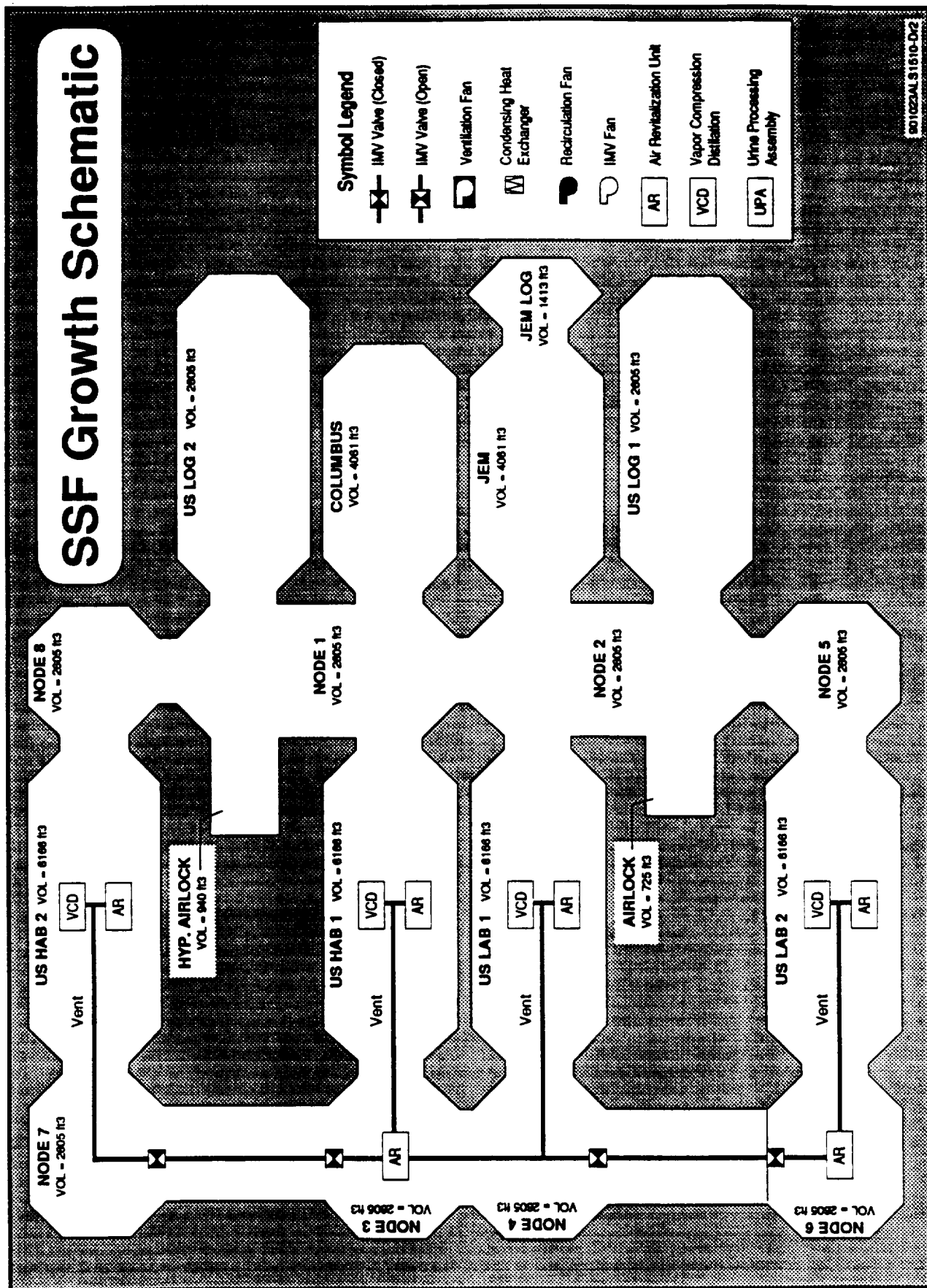


Figure 10 Crew Distributed



2. A Report on the Intermodule Ventilation Work Performed During Part 2

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Task 2 - ECLSS Evolution: Intermodule Ventilation Study

The purpose of this study was to perform intermodule ventilation studies for various Space Station Freedom (SSF) configurations and identify restrictions on the locations of additional modules. At the time when this task was initiated, NASA's Space Station Evolution Working Group had identified several space station growth concepts which were then used in this study of intermodule ventilation. Eight different growth configurations of the Space Station Freedom were analyzed including Eight Man Crew Configuration (EMCC), Research Configuration, Research and Transportation Configuration, Fourteen Man Crew Configuration (FMCC), Option C, Growth Option A, Growth Option B, and Growth Option C. The EMCC configuration served as the baseline and all other configuration were built up from this configuration. A complete set of presentation charts for this study are presented in Appendix B-1.

As reported in the executive summary, algorithms and computer models were developed to generate trade study results. The computer models were developed in SYMPHONY, an IBM PC based electronic spreadsheet, and were delivered to NASA. Prior to initiation of the studies, an overall set of study groundrules and guidelines were established as shown in Exhibit B-1, on following page.

Task 1 Trade Study Groundrules and Guidelines

- Steady State analysis only. No transient cases studied
- One Atmosphere Revitalization (AR) unit per 4 crew members
- Only the extreme options for ventilation were studied; racetrack and parallel.
- Only extreme options for crew location were studied; even disperation of crew among the modules and all crew concentrated in one module.
- Trade study variables were: ventilation path, crew location, AR location, and number of crew.
- Other variables which were not traded include: intermodule flow rate, CO₂ production rate, ambient pressure and temperature, and CO₂ removal rate.
- Dead-end connections always have parallel flow.
- ACRVs were not included in the ventilation paths.
- Several configurations are being studied: EMCC, Research, Transportation/Research, FMCC, EMCC Option C*, Module Pattern Growth Option A*, and others* TBD.

* per SSF Evolution Working Group Meeting, Reston, VA, April 4-5

- The predefined limits for CO₂ partial pressure are:
 - 3.0 mm Hg - maximum operational limit
 - 7.6 mm Hg - maximum degraded atmosphere limit
 - 12 mm Hg - Maximum emergency limit
- The following constants were applied to all trade studies:

Intermodule Air Flow Rate	130 CFM
CO ₂ Production Rate	2.2 lb/man-day
Total Pressure	760 mm HG @
Total Temperature	535 deg R
CO ₂ Removal Rate	0.1317*ppCO ₂

- The basic form of the equation used to solve for CO₂ Concentration is
- $$0 = \text{Source (crew)} - \text{Sink (AR)} + \text{CO}_2 \text{ in} - \text{CO}_2 \text{ out}$$

Exhibit B-1. Task 1 Trade Study Groundrules and Guidelines

The first configuration studied was the EMCC. This configuration is an "in-plane" configuration with 4 nodes, 2 habitation modules, 2 laboratory modules, an Assured Crew Return Vehicle (ACRV), an airlock, the Columbus/ESA module, and the Japanese Experiment Module (JEM). Thirty four individual cases were studies through using the EMCC computer model to generate the results. Exhibit B-2 is a description of the cases studied. Pertinent conclusions from the analyses of the EMCC results are:

- With two ARs operating (one each in Hab B and Lab B), regardless of the ventilation path and crew location, the partial pressure of CO₂ in the nodes and modules remains near the operational limit.
- In all cases studied, with only one AR operating, the operational limit is exceeded but the maximum degraded atmosphere limit of 7.6 mm is not exceeded.
- Crew concentration in one module versus even distribution of crew in several modules generally yields high concentrations of CO₂.
- Parallel ventilation paths provide lower CO₂ concentrations than racetrack ventilation paths.

Ventilation Path		Crew Location		AR Location			Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab B	AR in Lab B	AR in Lab D		
✓		✓	✓	✓			8	1
✓			✓	✓			8	9
	✓	✓	✓	✓			8	1
	✓		✓	✓			8	9
✓		✓	✓	✓	✓		8	1
✓			✓	✓	✓		8	9
	✓	✓	✓	✓	✓		8	1
	✓		✓	✓	✓		8	9
✓		✓	✓	✓	✓	✓	12	1
✓			✓	✓	✓	✓	12	9
	✓	✓	✓	✓	✓	✓	12	1
	✓		✓	✓	✓	✓	12	9

Exhibit B-2. EMCC Configuration Cases Studied

The second configuration which was studied was the Research configuration. This configuration builds on the EMCC by adding two additional lab modules "in-plane". A summary of the cases studied is presented in Exhibit B-3. The conclusions from the analyses of the Research configuration results are:

- With only one AR operating and a crew of 8, the operational limit is exceeded in most cases but the maximum degraded atmosphere limit is not exceeded in any case.
- With two ARs operating and a crew of 8, the operational limit is still exceeded in several cases but to a lesser degree than in cases with only one AR. Again, the maximum degraded atmosphere limit is not exceeded in any case.
- With two ARs operating, 8 crew, and parallel ventilation, the operational limit is only exceeded in a few cases.
- With three ARs operational and a crew of 12, the CO2 concentration generally exceeds the operational limit. However, parallel ventilation paths perform better than racetrack paths.

Ventilation Path		Crew Location		AR Location		Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab B	AR in Lab B	AR in Lab D	
✓		✓		✓			8 1
✓			✓	✓			8 9
	✓	✓		✓			8 1
	✓		✓	✓			8 9
✓		✓		✓	✓		8 1
✓			✓	✓	✓		8 9
	✓	✓		✓	✓		8 1
	✓		✓	✓	✓		8 9
✓		✓		✓	✓	✓	12 1
	✓		✓	✓	✓	✓	12 9
	✓	✓		✓	✓	✓	12 1
	✓		✓	✓	✓	✓	12 9

Exhibit B-3. Research Configuration Cases Studied

The third configuration studied was the Research and Transportation configuration. This configuration builds on the Research configuration by adding two addition habitation modules "in-

plane". Exhibit B-4 shows the cases studied for this configuration. The analyses of the Research and Transportation Configuration yielded these results:

- With 16 crew and 4 ARs operating, the maximum degraded atmosphere limit is only exceeded with a racetrack configuration and all 16 crew in the ESA module.
- The parallel ventilation path generally provides significantly lower CO₂ concentrations than the corresponding racetrack ventilation path.

Ventilation Path		Crew Location		AR Location				Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab B	AR in Lab B	AR in Hab D	AR in Lab D		
✓		✓		✓	✓	✓	✓	16	1
✓			✓	✓	✓	✓	✓	16	11
	✓	✓		✓	✓	✓	✓	16	1
	✓		✓	✓	✓	✓	✓	16	11

Exhibit B-4. Research and Transportation Configuration Cases Studied

The fourth configuration studied was the FMCC configuration. This configuration built on the EMCC baseline configuration by adding two additional habitation modules out-of-plane. The additional modules are connected to nodes 1 and 2. A summary of the cases studied is presented in Exhibit B-5. The analyses of the results determined that with 4 ARs operating and 12 crew, adequate ventilation to remain below the operational limit is provided in almost all cases. The operational limit is only exceeded in the cases where all 12 crew are concentrated in the JEM and ESA modules.

Ventilation Path		Crew Location		AR Location		Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab B	AR in Lab B		
✓		✓		✓	✓	12	1
✓			✓	✓	✓	12	9
	✓	✓		✓	✓	12	1
	✓		✓	✓	✓	12	9

Exhibit B-5. FMCC Configuration Cases Studied

The fifth case studied was the Option C configuration. This out-of-plane configuration contains the same elements as the EMCC but is arranged differently. A summary of the cases studied is given in Exhibit B-6. An the analyses of the Option C results identified that with 8 crew and two operating ARs , the operational limit is only exceeded in a few cases.

Ventilation Path		Crew Location		AR Location		Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab B	AR in Lab B		
✓		✓		✓	✓	8	1
✓			✓	✓	✓	8	6
	✓	✓		✓	✓	8	1
	✓		✓	✓	✓	8	6

Exhibit B-6. Option C Configuration Cases Studied

The sixth configuration studied was the Growth Option A configuration. This configuration is built up from the Option C configuration. It includes the addition of a habitation module, a laboratory module, and two nodes. The cases studied are outlined in Exhibit B-7. Analyses of this configuration determined that with 12 crew and 3 ARs operating, the operational limit is only reached in a few cases (JEM, Airlock 1, and ESA). Parallel ventilation is generally better.

Ventilation Path		Crew Location		AR Location		Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab B	AR in Lab B		
↓		↓		↓	↓	12	1
↓			↓	↓	↓	12	8
	↓	↓		↓	↓	12	1
	↓		↓	↓	↓	12	8

Exhibit B-7. Growth Option A Configuration Cases Studied

The seventh configuration studied was the Growth Option B configuration. This configuration has the same elements as Growth Option A but is arranged in an in-plane configuration. The cases studied are presented in Exhibit B-8. Analysis of the results concluded that with 12 crew and 3 ARs operating, the operational limit is exceeded in both parallel and racetrack ventilation paths.

Ventilation Path			Crew Location		AR Location		Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab B	AR in Lab A	AR in Lab C		
✓		✓		✓	✓	✓	12	1
✓			✓	✓	✓	✓	12	8
	✓	✓		✓	✓	✓	12	1
	✓		✓	✓	✓	✓	12	8

Exhibit B-8. Growth Option B Configuration Cases Studied

The final configuration that was analyzed was the Growth Option C configuration. This configuration is a rearrangement of the Growth Option A configuration. Exhibit B-9 shows the cases studied. Analyses of the results concluded that with 12 crew and 3 ARs operating, the operational limit is exceeded in most cases and the degraded atmosphere limit is exceeded in several cases. Further study of the AR locations should be done.

Ventilation Path			Crew Location		AR Location		Number of Crew	Number of Cases Run
Racetrack	Parallel	Even	Concentrated	AR in Hab A	AR in Lab B	AR in Lab C		
✓		✓		✓	✓	✓	12	1
✓			✓	✓	✓	✓	12	8
	✓	✓		✓	✓	✓	12	1
	✓		✓	✓	✓	✓	12	8

Exhibit B-9. Growth Option C Configuration Cases Studied

Overall, some general comments and conclusions were compiled from an analysis of the data and are presented in Exhibit B-10.

Conclusions

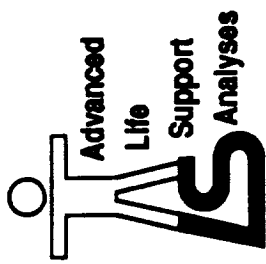
- The concentration of CO₂ can be held below the operational limit by one or more of the following methods:
 - 1) add additional operational ARs,
 - 2) reduce or avoid crew concentrations,
 - 3) improve the performance of the ARs
- Parallel ventilation paths generally provide lower CO₂ concentrations.
- The EMCC baseline configuration provides lower CO₂ concentrations than the EMCC Option C configuration.

Exhibit B-10. Task 1 Overall Conclusions

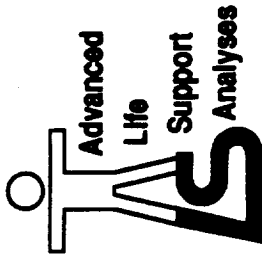
Appendix B-1
Part 2 Intermodule Ventilation Study Presentation Charts



SSF Evolution Concepts Ventilation Trade Studies

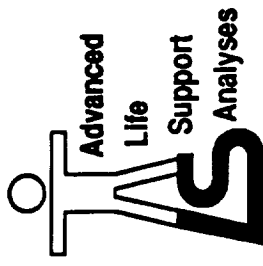


Trade Study Objectives



Objective: For evolutionary space station configurations, study the effect of various intermodule ventilation schemes on the concentration of CO₂ in nodes and modules.

Trade Study Groundrules and Guidelines



- Steady State analysis only. No transient cases studied
- One Atmosphere Revitalization (AR) unit per 4 crew members
- Only the extreme options for ventilation were studied; racetrack and parallel.
- Only extreme options for crew location were studied; even dispersion of crew among the modules and all crew concentrated in one module.
- Trade study variables were: ventilation path, crew location, AR location, and number of crew.
- Other variables which were not traded include: intermodule flow rate, CO₂ production rate, ambient pressure and temperature, and CO₂ removal rate.
- Dead-end connections always have parallel flow.
- ACRVs were not included in the ventilation paths.
- Several configurations are being studied: EMCC, Research, Transportation/Research, FMCC, EMCC Option C*, Module Pattern Growth Option A, Growth Option B, and Growth Option C.*

* per SSF Evolution Working Group Meeting, Reston, VA, April 4-5

- The predefined limits for CO₂ partial pressure are:
 - 3.0 mm Hg - maximum operational limit
 - 7.6 mm Hg - maximum degraded atmosphere limit
 - 12 mm Hg - Maximum emergency limit

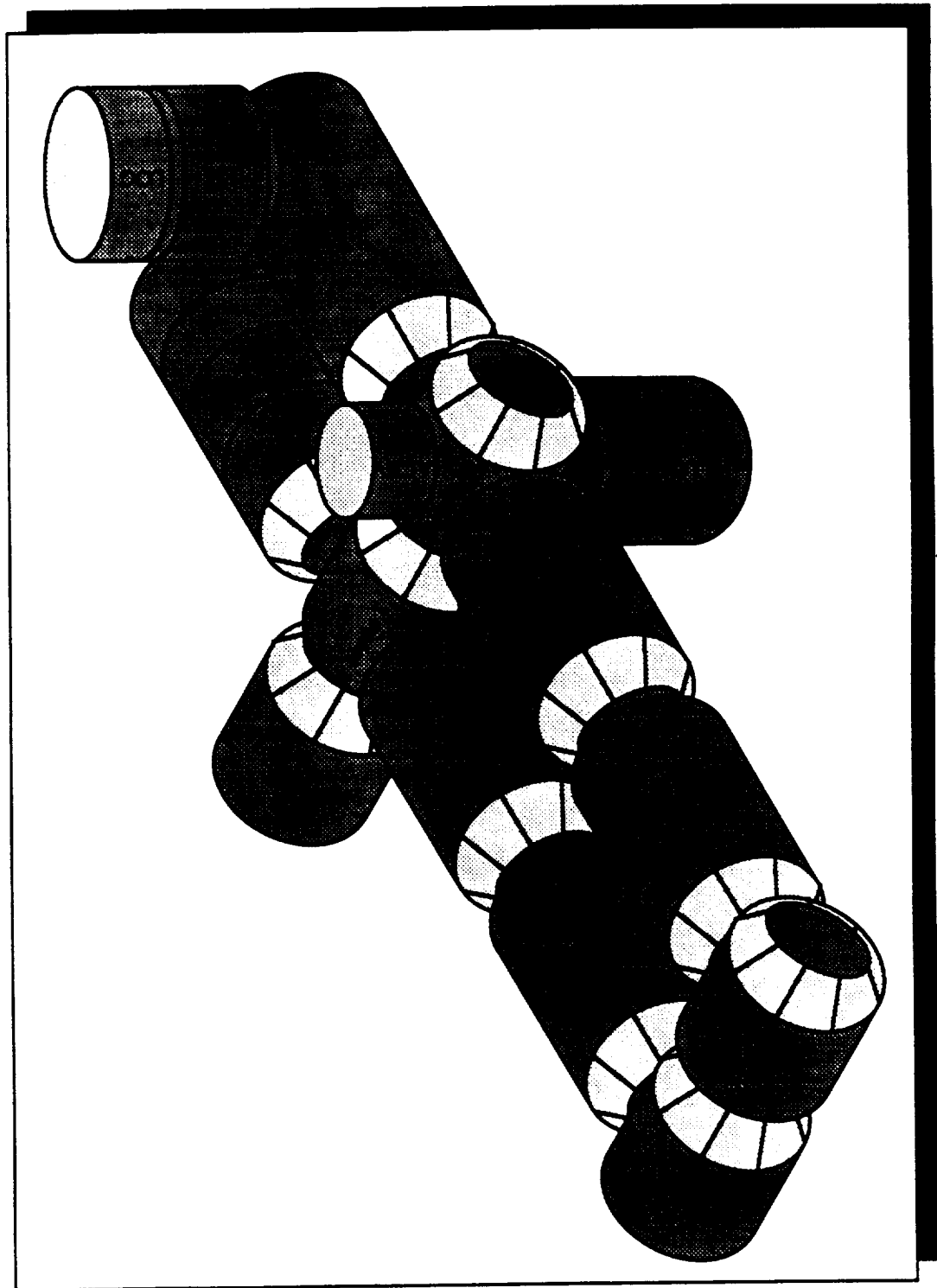
- The following constants were applied to all trade studies:

Intermodule Air Flow Rate	130 CFM
CO2 Production Rate	2.2 lb/man-day
Total Pressure	760 mm HG @
Total Temperature	535 deg R
CO2 Removal Rate	0.1317* ppCO2

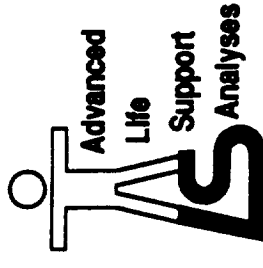
- The basic form of the equation used to solve for CO2 Concentration is

$$0 = \text{Source (crew)} - \text{Sink (AR)} + \text{CO}_2 \text{ in} - \text{CO}_2 \text{ out}$$

EMCC Baseline Configuration



EMCC Baseline Configuration Analysis of Trade Study Results



- With two ARs operating (one each in Hab B and Lab B), regardless of the ventilation path and crew location, the partial pressure of CO₂ in the nodes and modules remains near the operational limit.
- In all cases studied, with only one AR operating, the operational limit is exceeded but the maximum degraded atmosphere limit of 7.6 mm is not exceeded.
- Crew concentration in one module versus even distribution of crew in several modules generally yields high concentrations of CO₂.
- Parallel ventilation paths provide lower CO₂ concentrations than racetrack ventilation paths.

EMCC Configuration Trade Study Results (page 1)

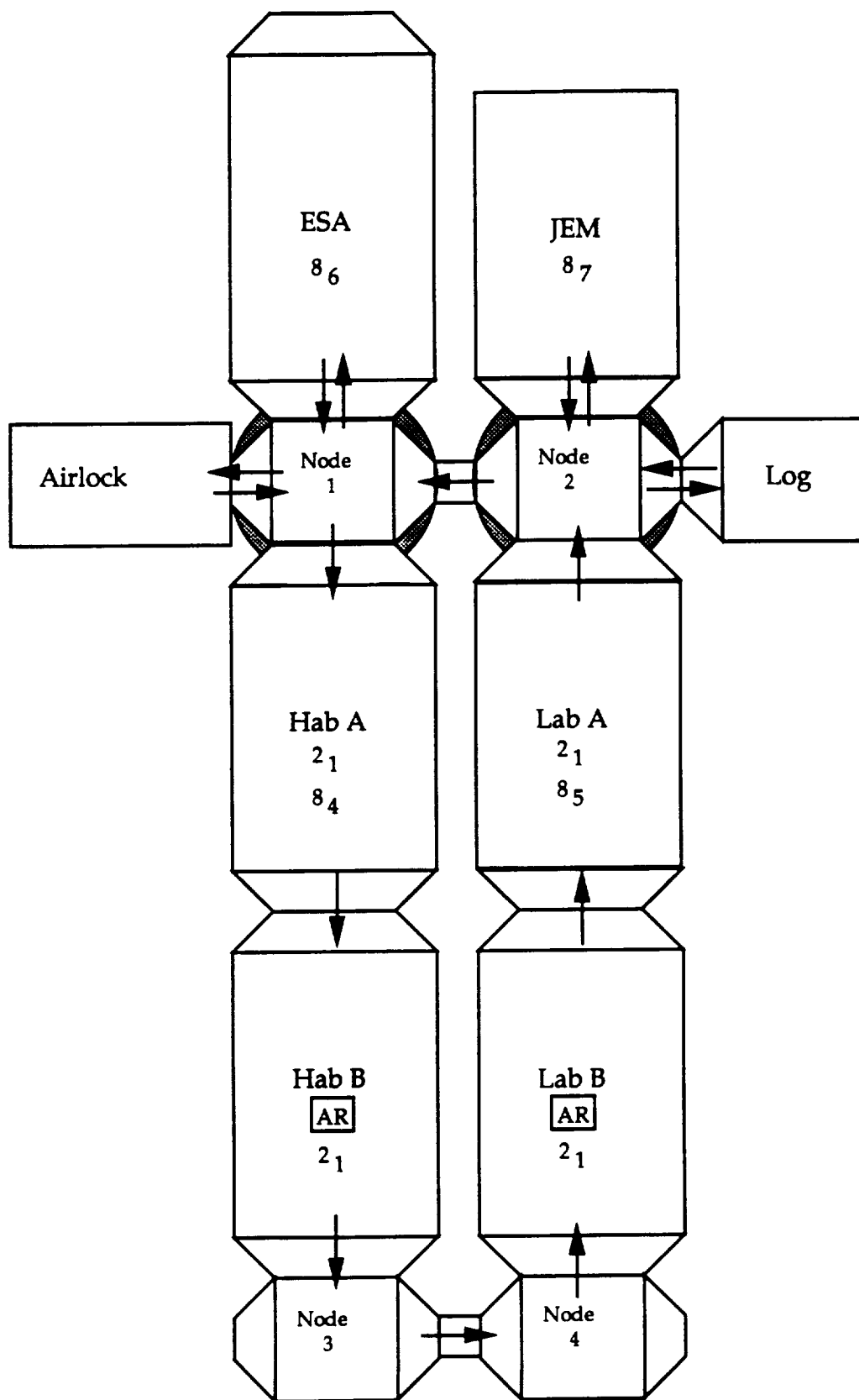
Case	Ventilation Path	Crew Location	AR Location	Hab A	Hab B	Lab A	Lab B	Node 1
EMCC-1	Racetrack	Even	AR in Hab B and Lab B	3.026212	2.85911	2.867655	2.7091	2.867655
EMCC-2	Racetrack	Even	AR in Hab B	6.04388	5.56821	5.885324	5.72677	5.885324
EMCC-3	Racetrack	Even	AR in Lab B	5.885324	6.04388	5.726767	5.56821	5.726767
EMCC-4	Racetrack	8 crew in Hab A	AR's in Hab B and Lab B	3.268319	2.93412	2.634092	2.63409	2.634092
EMCC-5	Racetrack	8 crew in Lab A	AR's in Hab B and Lab B	3.268319	2.93412	3.268319	2.63409	3.268319
EMCC-6	Racetrack	8 crew in ESA	AR's in Hab B and Lab B	3.268319	2.93412	2.634092	2.63409	3.268319
EMCC-7	Racetrack	8 crew in JEM	AR's in Hab B and Lab B	3.268319	2.93412	2.634092	2.63409	3.268319
EMCC-8	Racetrack	8 crew in Lab B	AR in Hab B	6.202437	5.56821	6.202437	6.20244	6.202437
EMCC-9	Racetrack	8 crew in Hab A	AR in Hab B	6.202437	5.56821	5.568211	5.56821	5.568211
EMCC-10	Racetrack	8 crew in Lab A	AR in Hab B	6.202437	5.56821	6.202437	5.56821	6.202437
EMCC-11	Racetrack	8 crew in ESA	AR in Hab B	6.202437	5.56821	5.568211	5.56821	6.202437
EMCC-12	Racetrack	8 crew in JEM	AR in Hab B	6.202437	5.56821	5.568211	5.56821	6.202437
EMCC-13	Racetrack	8 crew in Hab B	AR in Lab B	5.568211	6.20244	5.568211	5.56821	5.568211
EMCC-14	Racetrack	8 crew in Hab A	AR in Lab B	6.202437	6.20244	5.568211	5.56821	5.568211
EMCC-15	Racetrack	8 crew in Lab A	AR in Lab B	6.202437	6.20244	6.202437	5.56821	6.202437
EMCC-16	Racetrack	8 crew in ESA	AR in Lab B	6.202437	6.20244	5.568211	5.56821	6.202437
EMCC-17	Racetrack	8 crew in JEM	AR in Lab B	6.202437	6.20244	5.568211	5.56821	6.202437
EMCC-18	Parallel	Even	AR's in Hab B and Lab B	2.942662	2.78411	2.942662	2.78411	2.942662
EMCC-19	Parallel	8 crew in Hab A	AR's in Hab B and Lab B	3.388186	2.94527	2.814251	2.62294	3.196874
EMCC-20	Parallel	8 crew in Lab A	AR's in Hab B and Lab B	2.814251	2.62294	3.388186	2.94527	3.005563
EMCC-21	Parallel	8 crew in ESA	AR's in Hab B and Lab B	3.196874	2.83783	3.005563	2.73038	3.555922
EMCC-22	Parallel	8 crew in JEM	AR's in Hab B and Lab B	3.005563	2.73038	3.196874	2.83783	3.280742
EMCC-23	Parallel	Even	AR in Hab B	5.845685	5.56821	6.202437	6.1628	5.964602
EMCC-24	Parallel	8 crew in Lab B	AR in Hab B	5.806046	5.56821	6.51955	6.75739	6.04388
EMCC-25	Parallel	8 crew in Hab A	AR in Hab B	6.123159	5.56821	5.885324	5.80605	6.04388
EMCC-26	Parallel	8 crew in Lab A	AR in Hab B	5.885324	5.56821	6.836664	6.51955	6.202437
EMCC-27	Parallel	8 crew in ESA	AR in Hab B	6.04388	5.56821	6.202437	6.04388	6.51955
EMCC-28	Parallel	8 crew in JEM	AR in Hab B	6.04388	5.56821	6.202437	6.04388	6.51955
EMCC-29	Parallel	Even	AR in Lab B	6.202437	6.1628	5.845685	5.56821	6.08352
EMCC-30	Parallel	8 crew in Hab B	AR in Lab B	6.51955	6.75739	5.806046	5.56821	6.281715
EMCC-31	Parallel	8 crew in Hab A	AR in Lab B	6.836664	6.51955	5.885324	5.56821	6.51955
EMCC-32	Parallel	8 crew in Lab A	AR in Lab B	5.885324	5.80605	6.123159	5.56821	5.964602
EMCC-33	Parallel	8 crew in ESA	AR in Lab B	6.51955	6.28172	5.964602	5.56821	6.757385
EMCC-34	Parallel	8 crew in JEM	AR in Lab B	6.202437	6.04388	6.04388	5.56821	6.360994

EMCC Configuration Trade Study Results (page 2)

Case	Node 2	Node 3	Node 4	Log 1	ESA	IEM	Airlock	Totals
EMCC-1	2.86766	2.85911	2.85911	2.86766	2.867655	2.86766	2.86766	3.02621
EMCC-2	5.88532	5.56821	5.56821	5.88532	5.885324	5.88532	5.88532	6.04388
EMCC-3	5.72677	6.04388	6.04388	5.72677	5.726767	5.72677	5.72677	6.04388
EMCC-4	2.63409	2.93412	2.93412	2.63409	2.634092	2.63409	2.63409	3.26832
EMCC-5	3.26832	2.93412	2.93412	3.26832	3.268319	3.26832	3.26832	3.26832
EMCC-6	2.63409	2.93412	2.93412	2.63409	3.902545	2.63409	3.26832	3.90255
EMCC-7	3.26832	2.93412	2.93412	3.26832	3.268319	3.90255	3.26832	3.90255
EMCC-8	6.20244	5.56821	5.56821	6.20244	6.202437	6.20244	6.20244	6.20244
EMCC-9	5.56821	5.56821	5.56821	5.56821	5.568211	5.56821	5.56821	6.20244
EMCC-10	6.20244	5.56821	5.56821	6.20244	6.202437	6.20244	6.20244	6.20244
EMCC-11	5.56821	5.56821	5.56821	5.56821	6.836664	5.56821	6.20244	6.83666
EMCC-12	6.20244	5.56821	5.56821	6.20244	6.202437	6.83666	6.20244	6.83666
EMCC-13	5.56821	6.20244	6.20244	5.56821	5.568211	5.56821	5.56821	6.20244
EMCC-14	5.56821	6.20244	6.20244	5.56821	5.568211	5.56821	5.56821	6.20244
EMCC-15	6.20244	6.20244	6.20244	6.20244	6.202437	6.20244	6.20244	6.20244
EMCC-16	5.56821	6.20244	6.20244	5.56821	6.836664	5.56821	6.20244	6.83666
EMCC-17	6.20244	6.20244	6.20244	6.20244	6.202437	6.83666	6.20244	6.83666
EMCC-18	2.94266	2.78411	2.78411	2.94266	2.942662	2.94266	2.94266	2.94266
EMCC-19	3.00556	2.83783	2.73038	3.00556	3.196874	3.00556	3.19687	3.38819
EMCC-20	3.19687	2.73038	2.83783	3.19687	3.005563	3.19687	3.00556	3.38819
EMCC-21	3.28074	2.80201	2.7662	3.28074	4.190148	3.28074	3.55592	4.19015
EMCC-22	3.55592	2.7662	2.80201	3.55592	3.280742	4.19015	3.28074	4.19015
EMCC-23	6.08352	5.76641	5.9646	6.08352	5.964602	6.08352	5.9646	6.20244
EMCC-24	6.28172	5.9646	6.36099	6.28172	6.04388	6.28172	6.04388	6.75739
EMCC-25	5.9646	5.64749	5.72677	5.9646	6.04388	5.9646	6.04388	6.12316
EMCC-26	6.51955	5.88532	6.20244	6.51955	6.202437	6.51955	6.20244	6.83666
EMCC-27	6.36099	5.72677	5.88532	6.36099	7.153777	6.36099	6.51955	7.15378
EMCC-28	6.36099	5.72677	5.88532	6.36099	7.153777	6.36099	6.51955	7.15378
EMCC-29	5.9646	5.9646	5.76641	5.9646	6.08352	5.9646	6.08352	6.20244
EMCC-30	6.04388	6.36099	5.9646	6.04388	6.281715	6.04388	6.28172	6.75739
EMCC-31	6.20244	6.20244	5.88532	6.20244	6.51955	6.20244	6.51955	6.83666
EMCC-32	6.04388	5.72677	5.64749	6.04388	5.964602	6.04388	5.9646	6.12316
EMCC-33	6.36099	6.04388	5.80605	6.36099	7.391612	6.36099	6.75739	7.39161
EMCC-34	6.51955	5.88532	5.72677	6.51955	6.360994	7.15378	6.36099	7.15378
								7.39161

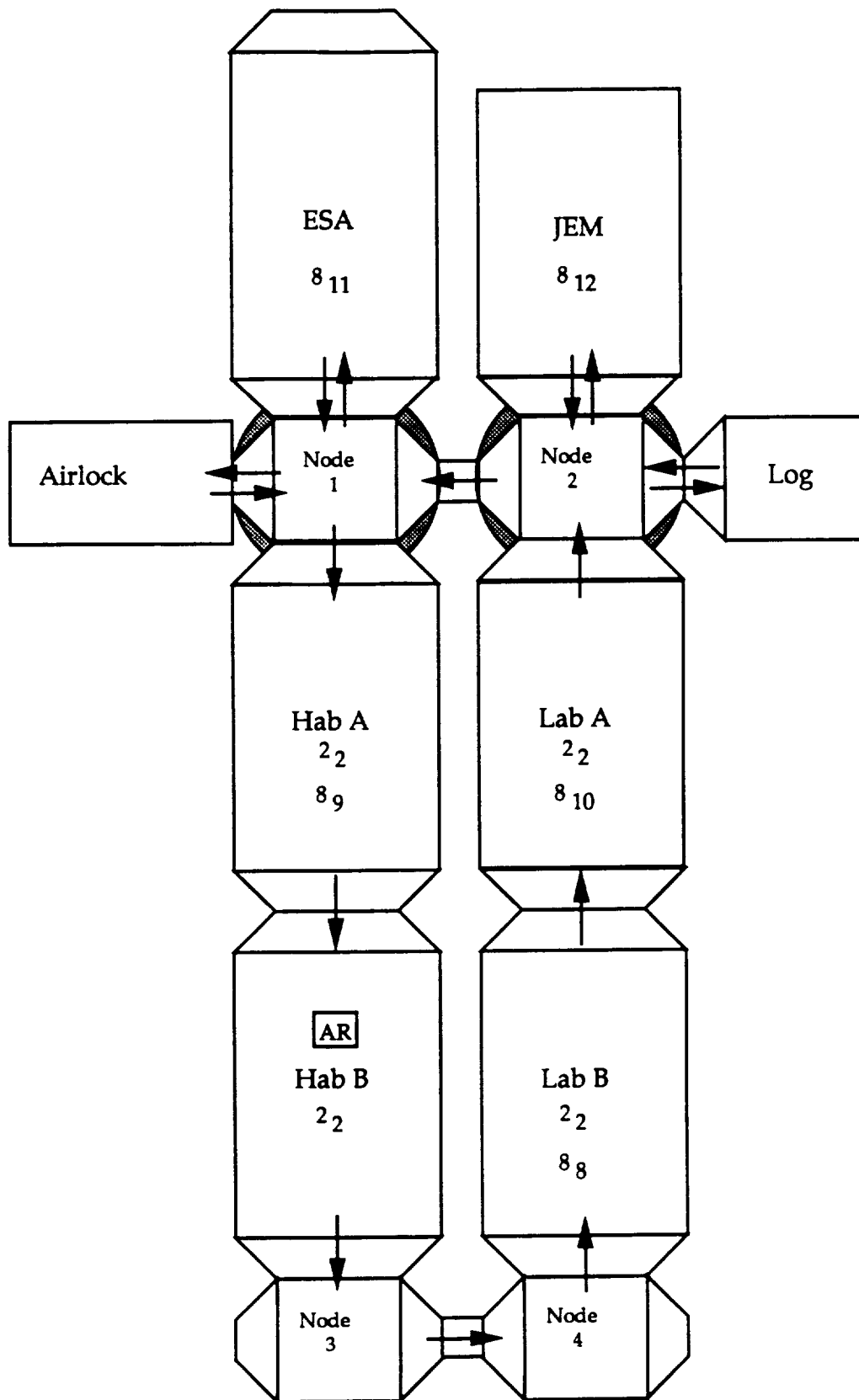
EMCC Baseline Configuration

Cases 1 & 4-7



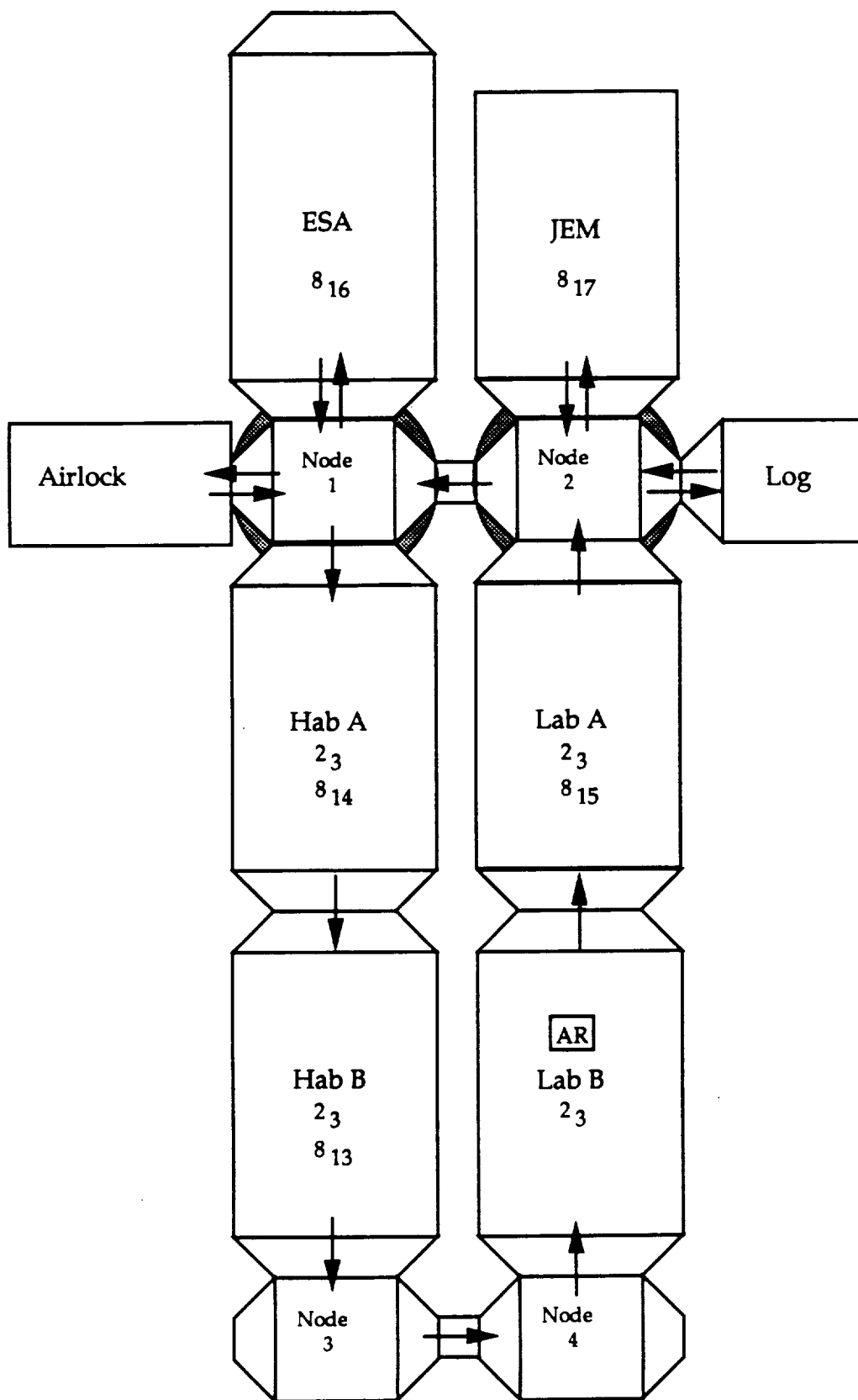
EMCC Baseline Configuration

Cases 2 & 8-12



EMCC Baseline Configuration

Cases 3 & 13-17

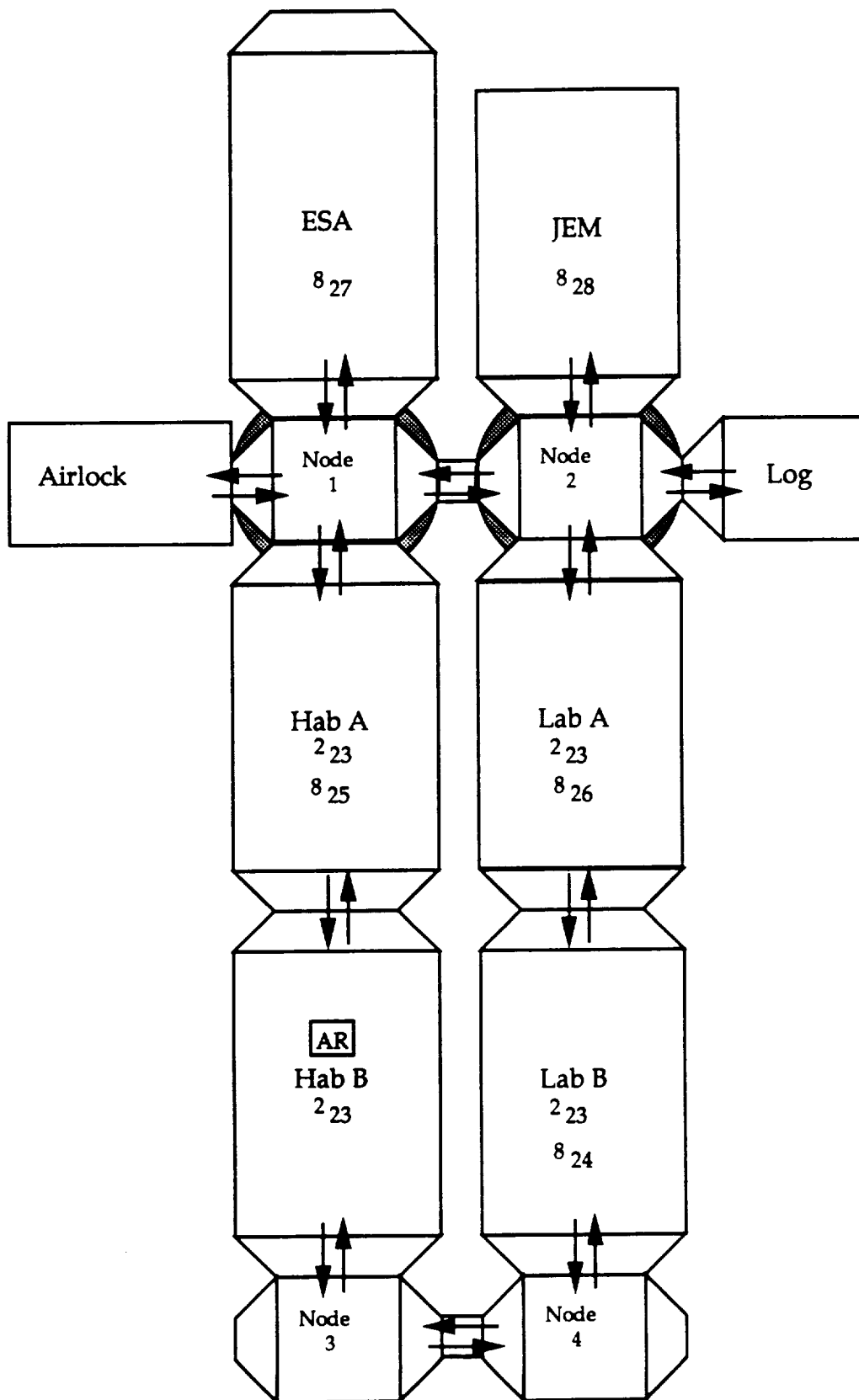


Cases 18-22



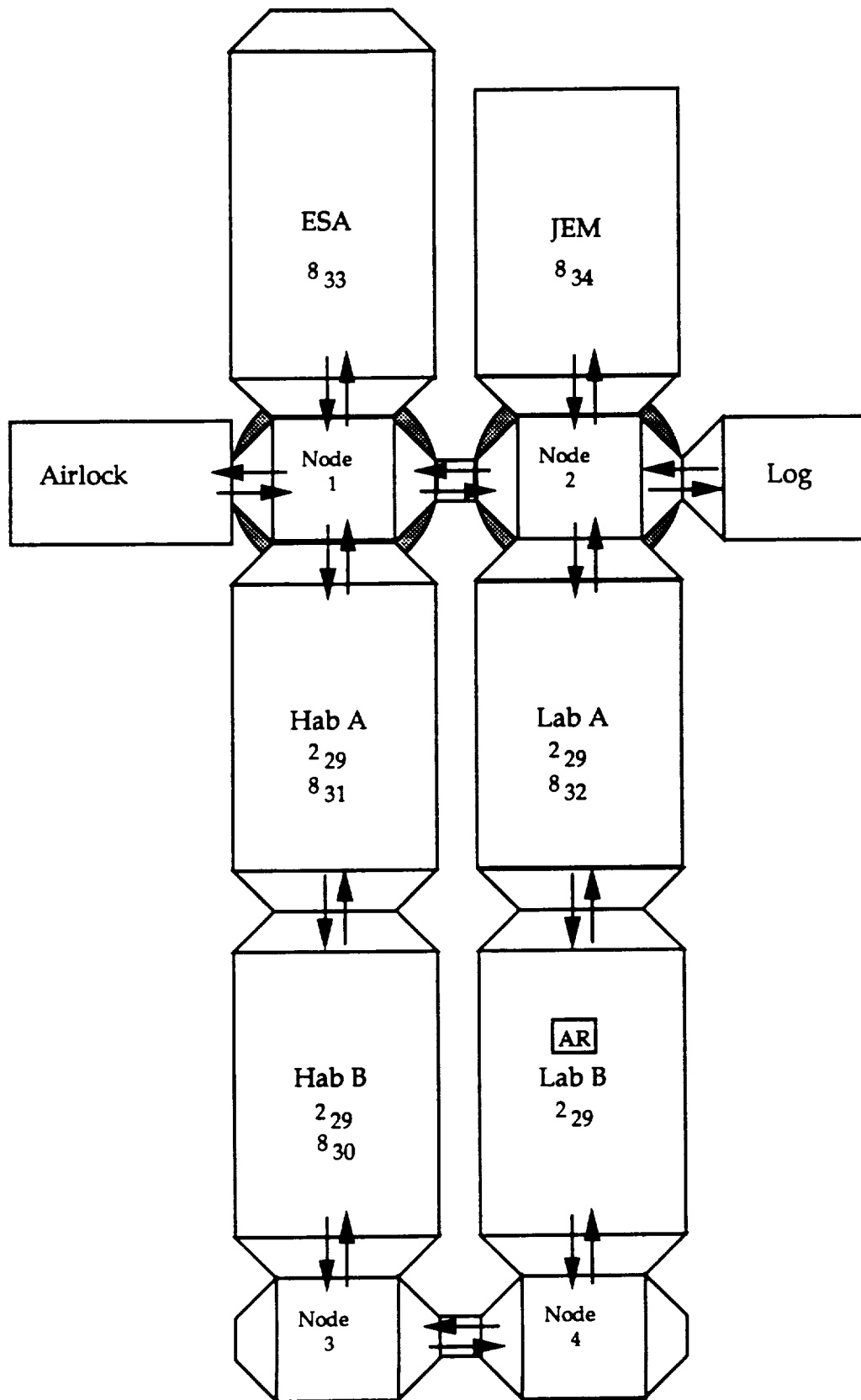
EMCC Baseline Configuration

Cases 23-28

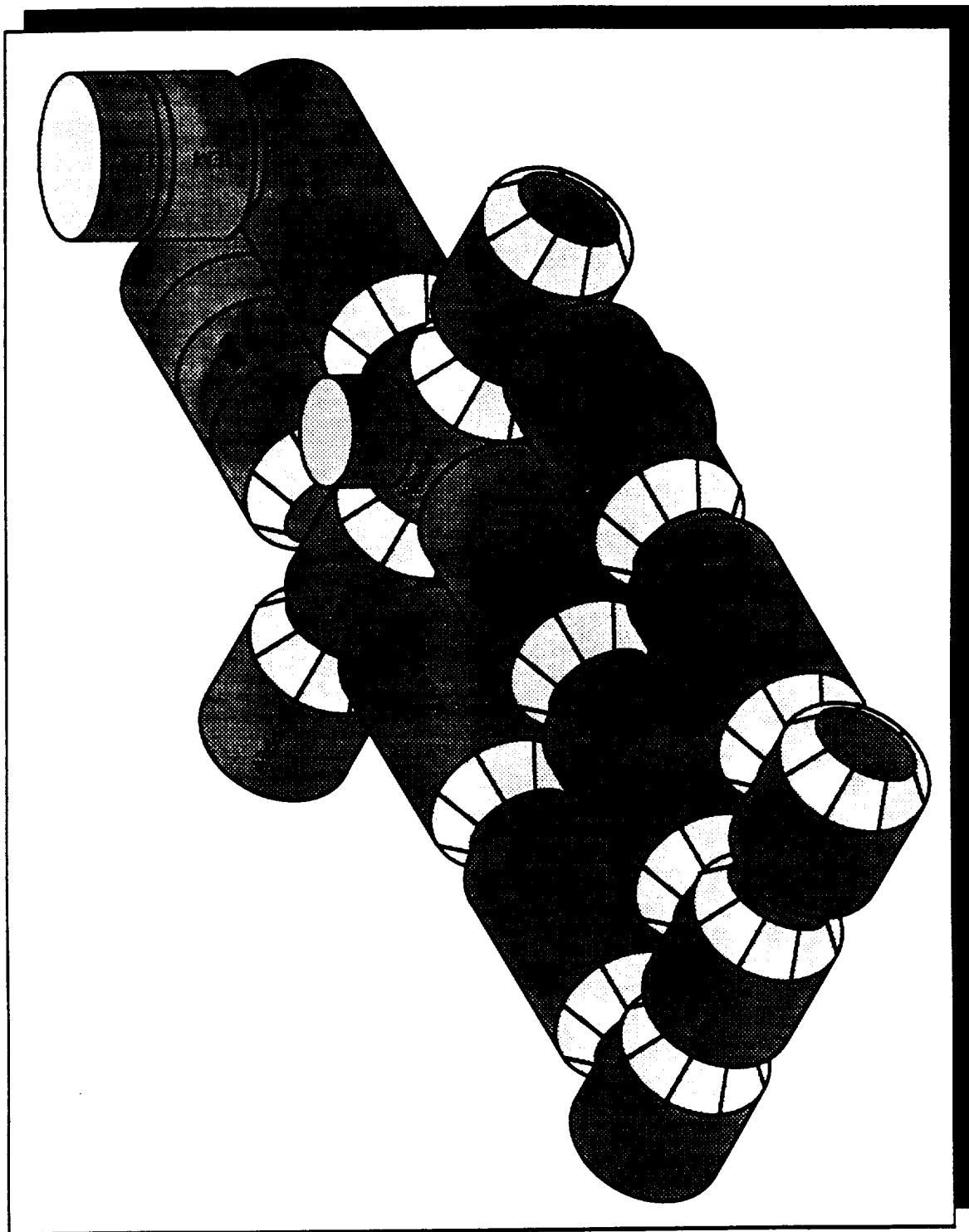


EMCC Baseline Configuration

Cases 29-34



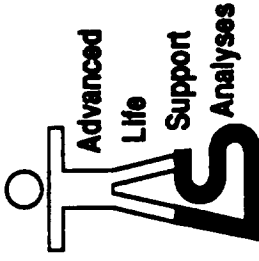
Research Configuration



Research Configuration Trade Study Summary

Ventilation Path		Crew Location		AR Location		Number of Crew		Number of Cases Run	
Race-track	Parallel	Even	Concentrated	AR in Hab B	AR in Lab B	AR in Lab D			
✓		✓		✓			8	1	
✓	✓	✓		✓			8	9	
✓	✓		✓	✓			8	1	
	✓		✓	✓			8	9	
✓	✓	✓	✓	✓	✓		8	1	
✓		✓	✓	✓	✓		8	9	
✓	✓	✓	✓	✓	✓		8	1	
	✓	✓	✓	✓	✓		8	9	
✓	✓	✓	✓	✓	✓	✓	12	1	
✓		✓		✓	✓	✓	12	9	
	✓		✓	✓	✓	✓	12	1	
	✓		✓	✓	✓	✓	12	9	

Research Configuration Analysis of Trade Study Results



- With only one AR operating and a crew of 8, the operational limit is exceeded in most cases but the maximum degraded atmosphere limit is not exceeded in any cases.
- With two ARs operating and a crew of 8, the operational limit is still exceeded in several cases but to a lesser degree than in cases with only one AR. Again, the maximum degraded atmosphere limit is not exceeded in any cases.
- With two ARs operating, 8 crew, and parallel ventilation, the operational limit is only exceeded in a few cases.
- With three ARs operation and a crew of 12, the CO₂ concentration generally exceeds the operational limit. However, parallel ventilation paths perform better than racetrack paths.

Results from Analysis of the Research Configuration (page 1)

Results	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4
RES-1; Racetrack, 8-Even, AR in Hab B	6.0439	5.5682	3.1012	2.9427	5.8853	5.8853	5.5682	2.7841
RES-2; Racetrack, 8-Hab B, AR in Hab B	5.5682	5.5682	2.7841	2.7841	5.5682	5.5682	5.5682	2.7841
RES-3; Racetrack, 8-Lab B, AR in Hab B	6.2024	5.5682	3.4183	3.4183	6.2024	6.2024	5.5682	2.7841
RES-4; Racetrack, 8-Lab D, AR in Hab B	6.2024	5.5682	2.7841	2.7841	6.2024	6.2024	5.5682	2.7841
RES-5; Racetrack, 8-Hab A, AR in Hab B	6.2024	5.5682	2.7841	2.7841	5.5682	5.5682	5.5682	2.7841
RES-6; Racetrack, 8-Lab A, AR in Hab B	6.2024	5.5682	3.4183	2.7841	6.2024	6.2024	5.5682	2.7841
RES-7; Racetrack, 8-Lab C, AR in Hab B	6.2024	5.5682	2.7841	2.7841	6.2024	6.2024	5.5682	2.7841
RES-8; Racetrack, 8-Airlock, AR in Hab B	6.2024	5.5682	2.7841	2.7841	6.2024	5.5682	5.5682	2.7841
RES-9; Racetrack, 8-ESA, AR in Hab B	6.2024	5.5682	2.7841	2.7841	6.2024	5.5682	5.5682	2.7841
RES-10; Racetrack, 8-JEM, AR in Hab B	6.2024	5.5682	2.7841	2.7841	6.2024	6.2024	5.5682	2.7841
RES-11; Parallel, 8-Even, AR in Hab B	5.8392	5.5682	6.1938	6.165	5.9516	6.0641	5.7729	5.9776
RES-12; Parallel, 8-Hab B, AR in Hab B	5.5682	5.5682	5.5682	5.5682	5.5682	5.5682	5.5682	5.5682
RES-13; Parallel, 8-Lab B, AR in Hab B	5.8104	5.5682	6.5253	6.7559	6.0525	6.2947	5.9603	6.3523
RES-14; Parallel, 8-Lab D, AR in Hab B	5.8219	5.5682	6.3293	6.3293	6.0756	6.3293	5.9487	6.3293
RES-15; Parallel, 8-Hab A, AR in Hab B	6.1102	5.5682	5.868	5.8104	6.0179	5.9257	5.6605	5.7527
RES-16; Parallel, 8-Lab A, AR in Hab B	6.1102	5.5682	5.868	5.8104	6.0179	5.9257	5.6605	5.7527
RES-17; Parallel, 8-Lab C, AR in Hab B	5.8565	5.5682	6.3754	6.3178	6.1448	6.4331	5.9142	6.2601
RES-18; Parallel, 8-Airlock, AR in Hab B	6.0179	5.5682	6.1678	6.0525	6.4677	6.2832	5.7527	5.9372
RES-19; Parallel, 8-ESA, AR in Hab B	6.0179	5.5682	6.1678	6.0525	6.4677	6.2832	5.7527	5.9372
RES-20; Parallel, 8-JEM, AR in Hab B	5.9257	5.5682	6.4677	6.2947	6.2832	6.6406	5.845	6.1217

Results from Analysis of the Research Configuration (page 2)

Results	Log 1	ESA	JEM	Airlock	Lab C	Lab D	Node 7	Node 8	Maximum
RES-1; Racetrack, 8-Even, AR in Hab B	5.8853	5.8853	5.8853	5.88532	2.7841	2.7841	2.7841	2.7841	6.04388
RES-2; Racetrack, 8-Hab B, AR in Hab B	5.5682	5.5682	5.5682	5.56821	2.7841	2.7841	2.7841	2.7841	5.56821
RES-3; Racetrack, 8-Lab B, AR in Hab B	6.2024	6.2024	6.2024	6.20244	2.7841	2.7841	2.7841	2.7841	6.20244
RES-4; Racetrack, 8-Lab D, AR in Hab B	6.2024	6.2024	6.2024	6.20244	3.4183	3.4183	3.4183	2.7841	6.20244
RES-5; Racetrack, 8-Hab A, AR in Hab B	5.5682	5.5682	5.5682	5.56821	2.7841	2.7841	2.7841	2.7841	6.20244
RES-6; Racetrack, 8-Lab A, AR in Hab B	6.2024	6.2024	6.2024	6.20244	2.7841	2.7841	2.7841	2.7841	6.20244
RES-7; Racetrack, 8-Lab C, AR in Hab B	6.2024	6.2024	6.2024	6.20244	3.4183	2.7841	3.4183	2.7841	6.20244
RES-8; Racetrack, 8-Airlock, AR in Hab B	5.5682	6.2024	5.5682	6.83666	2.7841	2.7841	2.7841	2.7841	6.83666
RES-9; Racetrack, 8-ESA, AR in Hab B	5.5682	6.8367	5.5682	6.20244	2.7841	2.7841	2.7841	2.7841	6.83666
RES-10; Racetrack, 8-JEM, AR in Hab B	6.2024	6.2024	6.8367	6.20244	2.7841	2.7841	2.7841	2.7841	6.83666
RES-11; Parallel, 8-Even, AR in Hab B	6.0641	5.9516	6.0641	5.95163	6.0295	6.0122	6.0468	5.9949	6.19379
RES-12; Parallel, 8-Hab B, AR in Hab B	5.5682	5.5682	5.5682	5.56821	5.5682	5.5682	5.5682	5.5682	5.56821
RES-13; Parallel, 8-Lab B, AR in Hab B	6.2947	6.0525	6.2947	6.05253	6.3178	6.3293	6.3062	6.3408	6.75594
RES-14; Parallel, 8-Lab D, AR in Hab B	6.3293	6.0756	6.3293	6.07559	6.8367	7.0904	6.583	6.7098	7.09035
RES-15; Parallel, 8-Hab A, AR in Hab B	5.9257	6.0179	5.9257	6.01793	5.8565	5.8219	5.8911	5.7873	6.11019
RES-16; Parallel, 8-Lab A, AR in Hab B	5.9257	6.0179	5.9257	6.01793	5.8565	5.8219	5.8911	5.7873	6.11019
RES-17; Parallel, 8-Lab C, AR in Hab B	6.4331	6.1448	6.4331	6.14478	7.1249	6.8367	6.779	6.5484	7.12495
RES-18; Parallel, 8-Airlock, AR in Hab B	6.2832	6.4677	6.2832	7.10189	6.1448	6.0756	6.214	6.0064	7.10189
RES-19; Parallel, 8-ESA, AR in Hab B	6.2832	7.1019	6.2832	6.46766	6.1448	6.0756	6.214	6.0064	7.10189
RES-20; Parallel, 8-JEM, AR in Hab B	6.6406	6.2832	7.2749	6.28316	6.4331	6.3293	6.5368	6.2255	7.27486

Results from the Analysis of the Research Configuration (page 3)

Results	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4
RES-21; Racetrack, 8-Even, AR in Hab B & Lab B	4.01288	3.744888	1.981879	1.823322	3.854323	3.854323	3.744888	1.872444
RES-22; Racetrack, 8-Hab B, AR in Hab B & Lab B	3.646644	3.843133	1.725078	1.725078	3.646644	3.646644	3.843133	1.921566
RES-23; Racetrack, 8-Lab B, AR in Hab B & Lab B	3.646644	3.843133	1.725078	1.725078	3.646644	3.646644	3.843133	1.921566
RES-24; Racetrack, 8-Lab D, AR in Hab B & Lab B	4.280871	3.843133	1.725078	1.725078	4.280871	4.280871	3.843133	1.921566
RES-25; Racetrack, 8-Hab A, AR in Hab B & Lab B	4.280871	3.843133	1.725078	1.725078	3.646644	3.646644	3.843133	1.921566
RES-26; Racetrack, 8-Lab A, AR in Hab B & Lab B	4.280871	3.843133	2.359304	1.725078	4.280871	4.280871	3.843133	1.921566
RES-27; Racetrack, 8-Lab C, AR in Hab B & Lab B	4.280871	3.843133	1.725078	1.725078	4.280871	4.280871	3.843133	1.921566
RES-28; Racetrack, 8-Airlock, AR in Hab B & Lab B	4.280871	3.843133	1.725078	1.725078	4.280871	3.646644	3.843133	1.921566
RES-29; Racetrack, 8-ESA, AR in Hab B & Lab B	4.280871	3.843133	1.725078	1.725078	4.280871	3.646644	3.843133	1.921566
RES-30; Racetrack, 8-JEM, AR in Hab B & Lab B	4.280871	3.843133	1.725078	1.725078	4.280871	4.280871	3.843133	1.921566
RES-31; Parallel, 8-Even, AR in Hab B & Lab B	2.932654	2.782803	2.929604	2.785408	2.923949	2.915244	2.79136	2.799916
RES-32; Parallel, 8-Hab B, AR in Hab B & Lab B	2.943011	3.052422	2.619989	2.515789	2.833601	2.72419	2.875281	2.69814
RES-33; Parallel, 8-Lab B, AR in Hab B & Lab B	2.625199	2.515789	2.948221	3.052422	2.73461	2.844021	2.69293	2.870071
RES-34; Parallel, 8-Lab D, AR in Hab B & Lab B	2.837885	2.70856	2.978094	2.859651	2.967211	3.096537	2.887743	3.066926
RES-35; Parallel, 8-Hab A, AR in Hab B & Lab B	3.370818	2.943011	2.791589	2.625199	3.164398	2.957978	2.850418	2.757824
RES-36; Parallel, 8-Lab A, AR in Hab B & Lab B	2.791589	2.619989	3.358617	2.948221	2.963188	3.134787	2.74681	2.873631
RES-37; Parallel, 8-Lab C, AR in Hab B & Lab B	2.877916	2.71377	3.030325	2.854441	3.042063	3.206209	2.858726	3.003681
RES-38; Parallel, 8-Airlock, AR in Hab B & Lab B	3.164398	2.833601	2.963188	2.73461	3.495195	3.191766	2.825554	2.817508
RES-39; Parallel, 8-ESA, AR in Hab B & Lab B	3.164398	2.833601	2.963188	2.73461	3.495195	3.191766	2.825554	2.817508
RES-40; Parallel, 8-JEM, AR in Hab B & Lab B	2.957978	2.72419	3.134787	2.844021	3.191766	3.425553	2.800691	2.877192

Results from the Analysis of the Research Configuration (page 4)

Results	Log 1	ESA	JEM	Airlock	Lab C	Lab D	Node 7	Node 8	Maximum
RES-21; Racetrack, 8-Even, AR in Hab B & Lab B	3.854323	3.854323	3.854323	3.85432296	1.872444	1.872444	1.872444	1.872444	4.01288
RES-22; Racetrack, 8-Hab B, AR in Hab B & Lab B	3.646644	3.646644	3.646644	3.64664418	1.921566	1.921566	1.921566	1.921566	3.843133
RES-23; Racetrack, 8-Lab B, AR in Hab B & Lab B	3.646644	3.646644	3.646644	3.64664418	1.921566	1.921566	1.921566	1.921566	3.843133
RES-24; Racetrack, 8-Lab D, AR in Hab B & Lab B	4.280871	4.280871	4.280871	4.28087067	2.555793	2.555793	2.555793	1.921566	4.280871
RES-25; Racetrack, 8-Hab A, AR in Hab B & Lab B	3.646644	3.646644	3.646644	3.64664418	1.921566	1.921566	1.921566	1.921566	4.280871
RES-26; Racetrack, 8-Lab A, AR in Hab B & Lab B	4.280871	4.280871	4.280871	4.28087067	1.921566	1.921566	1.921566	1.921566	4.280871
RES-27; Racetrack, 8-Lab C, AR in Hab B & Lab B	4.280871	4.280871	4.280871	4.28087067	2.555793	1.921566	2.555793	1.921566	4.280871
RES-28; Racetrack, 8-Airlock, AR in Hab B & Lab B	3.646644	4.280871	3.646644	4.91509717	1.921566	1.921566	1.921566	1.921566	4.915097
RES-29; Racetrack, 8-ESA, AR in Hab B & Lab B	3.646644	4.915097	3.646644	4.28087067	1.921566	1.921566	1.921566	1.921566	4.915097
RES-30; Racetrack, 8-JEM, AR in Hab B & Lab B	4.280871	4.280871	4.915097	4.28087067	1.921566	1.921566	1.921566	1.921566	4.915097
RES-31; Parallel, 8-Even, AR in Hab B & Lab B	2.915244	2.923949	2.915244	2.92394903	2.869113	2.846047	2.892178	2.822982	2.932654
RES-32; Parallel, 8-Hab B, AR in Hab B & Lab B	2.72419	2.833601	2.72419	2.83360057	2.71377	2.70856	2.71898	2.70335	3.052422
RES-33; Parallel, 8-Lab B, AR in Hab B & Lab B	2.844021	2.73461	2.844021	2.73461001	2.854441	2.859651	2.849231	2.864861	3.052422
RES-34; Parallel, 8-Lab D, AR in Hab B & Lab B	3.096537	2.967211	3.096537	2.96721097	3.592073	3.839842	3.344305	3.453384	3.839842
RES-35; Parallel, 8-Hab A, AR in Hab B & Lab B	2.957978	3.164398	2.957978	3.16439774	2.877916	2.837885	2.917947	2.797855	3.370818
RES-36; Parallel, 8-Lab A, AR in Hab B & Lab B	3.134787	2.963188	3.134787	2.96318779	3.030325	2.978094	3.082556	2.925862	3.358617
RES-37; Parallel, 8-Lab C, AR in Hab B & Lab B	3.206209	3.042063	3.206209	3.0420625	3.88627	3.592073	3.546239	3.297877	3.88627
RES-38; Parallel, 8-Airlock, AR in Hab B & Lab B	3.191766	3.495195	3.191766	4.12942141	3.042063	2.967211	3.116914	2.892359	4.129421
RES-39; Parallel, 8-ESA, AR in Hab B & Lab B	3.191766	4.129421	3.191766	3.49519491	3.042063	2.967211	3.116914	2.892359	4.129421
RES-40; Parallel, 8-JEM, AR in Hab B & Lab B	3.425553	3.191766	4.05978	3.19176558	3.206209	3.096537	3.315881	2.986864	4.05978

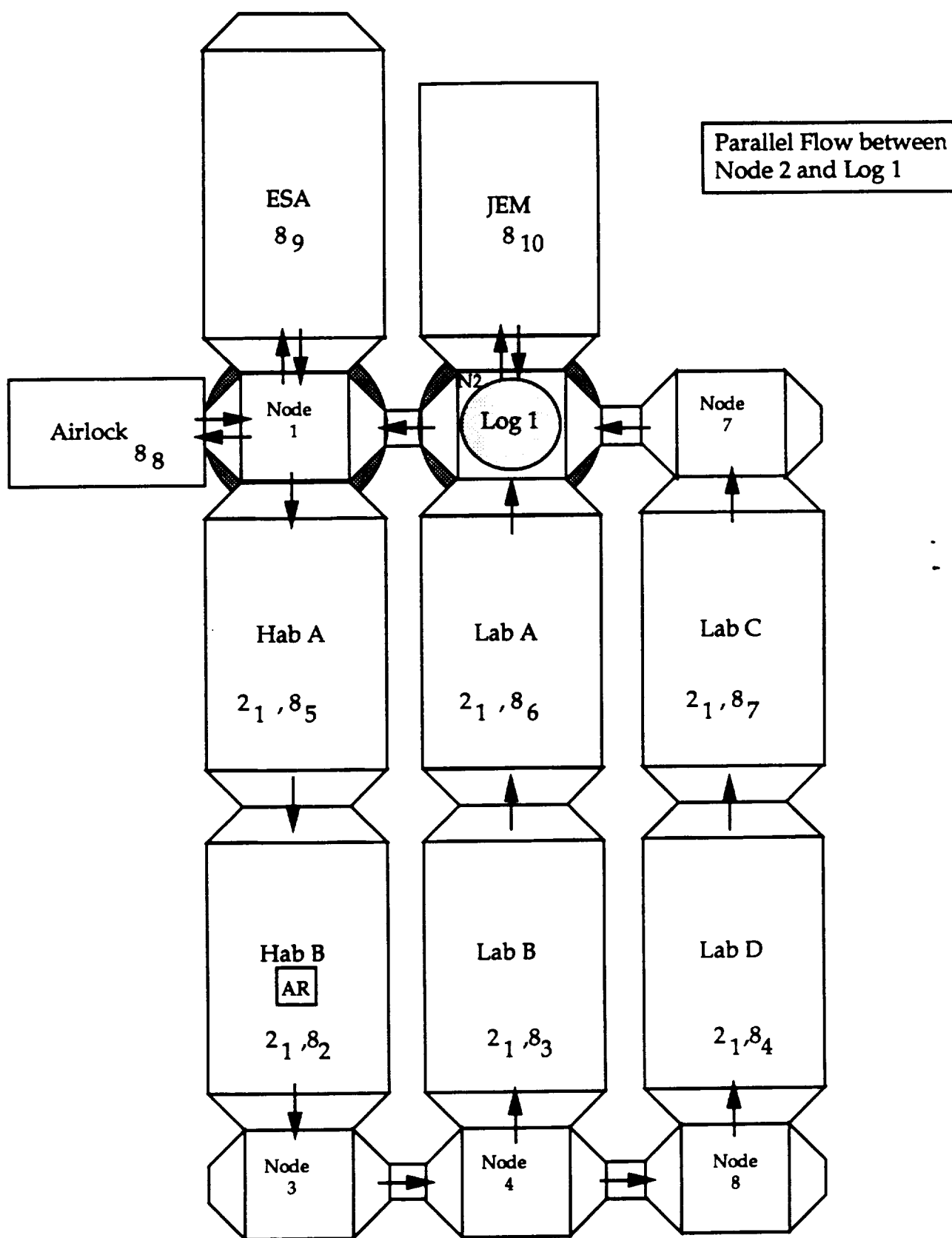
Results from the Analysis of the Research Configuration (page 5)

Results	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4
RES-41; Racetrack, 12-Even, AR in Hab B, Lab B, & Lab D	4.576821	4.251165	2.209132	2.050576	4.418265	4.418265	4.251165	2.125582
RES-42; Racetrack, 12-Hab B, AR in Hab B, Lab B, & Lab D	3.951138	4.401178	1.975569	1.975569	3.951138	3.951138	4.401178	2.200589
RES-43; Racetrack, 12-Lab B, AR in Hab B, Lab B, & Lab D	4.401178	3.951138	2.627619	2.627619	4.401178	4.401178	3.951138	1.975569
RES-44; Racetrack, 12-Lab D, AR in Hab B, Lab B, & Lab D	4.401178	3.951138	1.773558	1.773558	4.401178	4.401178	3.951138	1.975569
RES-45; Racetrack, 12-Hab A, AR in Hab B, Lab B, & Lab D	4.902478	4.401178	1.975569	1.975569	3.951138	3.951138	4.401178	2.200589
RES-46; Racetrack, 12-Lab A, AR in Hab B, Lab B, & Lab D	4.902478	4.401178	2.926909	1.975569	4.902478	4.902478	4.401178	2.200589
RES-47; Racetrack, 12-Lab C, AR in Hab B, Lab B, & Lab D	4.902478	4.401178	1.975569	1.975569	4.902478	4.902478	4.401178	2.200589
RES-48; Racetrack, 12-Airlock, AR in Hab B, Lab B, & Lab D	4.902478	4.401178	1.975569	1.975569	4.902478	3.951138	4.401178	2.200589
RES-49; Racetrack, 12-ESA, AR in Hab B, Lab B, & Lab D	4.902478	4.401178	1.975569	1.975569	4.902478	3.951138	4.401178	2.200589
RES-50; Racetrack, 12-JEM, AR in Hab B, Lab B, & Lab D	4.902478	4.401178	1.975569	1.975569	4.902478	4.902478	4.401178	2.200589
RES-51; Parallel, 12-Even, AR in Hab B, Lab B, & Lab D	2.942662	2.784105	2.942662	2.784105	2.942662	2.942662	2.784105	2.784105
RES-52; Parallel, 12-Hab B, AR in Hab B, Lab B, & Lab D	3.188984	3.408949	2.643903	2.538751	2.96902	2.749055	3.065858	2.722767
RES-53; Parallel, 12-Lab B, AR in Hab B, Lab B, & Lab D	2.643903	2.538751	3.06451	3.274813	2.749055	2.854206	2.722767	2.906782
RES-54; Parallel, 12-Lab D, AR in Hab B, Lab B, & Lab D	2.519428	2.404615	2.643903	2.538751	2.634242	2.749055	2.563691	2.722767
RES-55; Parallel, 12-Hab A, AR in Hab B, Lab B, & Lab D	3.772179	3.188984	2.839895	2.643903	3.404033	3.035888	2.96902	2.749055
RES-56; Parallel, 12-Lab A, AR in Hab B, Lab B, & Lab D	2.839895	2.643903	3.623865	3.06451	3.035888	3.23188	2.749055	2.854206
RES-57; Parallel, 12-Lab C, AR in Hab B, Lab B, & Lab D	2.691582	2.519428	2.839895	2.643903	2.863735	3.035888	2.634242	2.749055
RES-58; Parallel, 12-Airlock, AR in Hab B, Lab B, & Lab D	3.404033	2.96902	3.035888	2.749055	3.839047	3.322721	2.872181	2.775343
RES-59; Parallel, 12-ESA, AR in Hab B, Lab B, & Lab D	3.404033	2.96902	3.035888	2.749055	3.839047	3.322721	2.872181	2.775343
RES-60; Parallel, 12-JEM, AR in Hab B, Lab B, & Lab D	3.035888	2.749055	3.23188	2.854206	3.322721	3.609554	2.775343	2.801631

Results from the Analysis of the Research Configuration (page 6)

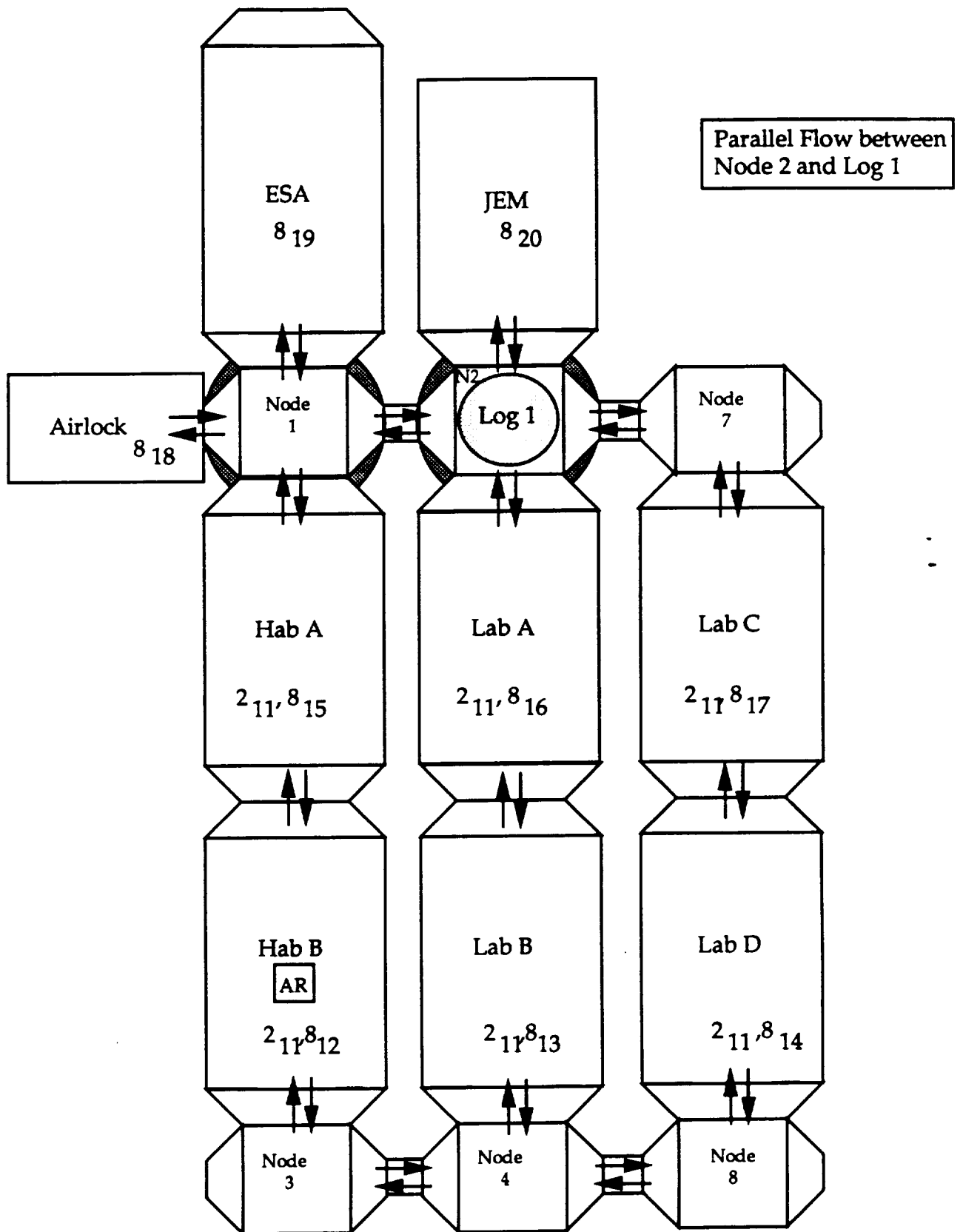
Results	Log 1	ESA	JEM	Airlock	Lab C	Lab D	Node 7	Node 8	Maximum
RES-41; Racetrack, 12-Even, AR in Hab B, Lab B, & Lab D	4.418265	4.418265	4.418265	4.41826455	2.209132	2.050576	2.209132	2.125582	4.57682117
RES-42; Racetrack, 12-Hab B, AR in Hab B, Lab B, & Lab D	3.951138	3.951138	3.951138	3.95113803	1.975569	1.975569	1.975569	2.200589	4.40117784
RES-43; Racetrack, 12-Lab B, AR in Hab B, Lab B, & Lab D	4.401178	4.401178	4.401178	4.40117784	1.773558	1.773558	1.773558	1.975569	4.40117784
RES-44; Racetrack, 12-Lab D, AR in Hab B, Lab B, & Lab D	4.401178	4.401178	4.401178	4.40117784	2.627619	2.627619	2.627619	1.975569	4.40117784
RES-45; Racetrack, 12-Hab A, AR in Hab B, Lab B, & Lab D	3.951138	3.951138	3.951138	3.95113803	1.975569	1.975569	1.975569	2.200589	4.90247777
RES-46; Racetrack, 12-Lab A, AR in Hab B, Lab B, & Lab D	4.902478	4.902478	4.902478	4.90247777	1.975569	1.975569	1.975569	2.200589	4.90247777
RES-47; Racetrack, 12-Lab C, AR in Hab B, Lab B, & Lab D	4.902478	4.902478	4.902478	4.90247777	2.926909	1.975569	2.926909	2.200589	4.90247777
RES-48; Racetrack, 12-Airlock, AR in Hab B, Lab B, & Lab D	3.951138	4.902478	3.951138	5.85381752	1.975569	1.975569	1.975569	2.200589	5.85381752
RES-49; Racetrack, 12-ESA, AR in Hab B, Lab B, & Lab D	3.951138	5.853818	3.951138	4.90247777	1.975569	1.975569	1.975569	2.200589	5.85381752
RES-50; Racetrack, 12-JEM, AR in Hab B, Lab B, & Lab D	4.902478	4.902478	5.853818	4.90247777	1.975569	1.975569	1.975569	2.200589	5.85381752
RES-51; Parallel, 12-Even, AR in Hab B, Lab B, & Lab D	2.942662	2.942662	2.942662	2.94266191	2.942662	2.784105	2.942662	2.784105	2.94266191
RES-52; Parallel, 12-Hab B, AR in Hab B, Lab B, & Lab D	2.749055	2.96902	2.749055	2.96901953	2.519428	2.404615	2.634242	2.563691	3.40894913
RES-53; Parallel, 12-Lab B, AR in Hab B, Lab B, & Lab D	2.854206	2.749055	2.854206	2.74905473	2.643903	2.538751	2.749055	2.722767	3.27481312
RES-54; Parallel, 12-Lab D, AR in Hab B, Lab B, & Lab D	2.749055	2.634242	2.749055	2.63424161	3.188984	3.408949	2.96902	3.065858	3.40894913
RES-55; Parallel, 12-Hab A, AR in Hab B, Lab B, & Lab D	3.035888	3.404033	3.035888	3.40403319	2.691582	2.519428	2.863735	2.634242	3.77217864
RES-56; Parallel, 12-Lab A, AR in Hab B, Lab B, & Lab D	3.23188	3.035888	3.23188	3.03588775	2.839895	2.643903	3.035888	2.749055	3.62386481
RES-57; Parallel, 12-Lab C, AR in Hab B, Lab B, & Lab D	3.035888	2.863735	3.035888	2.86373466	3.772179	3.188984	3.404033	2.96902	3.77217864
RES-58; Parallel, 12-Airlock, AR in Hab B, Lab B, & Lab D	3.322721	3.839047	3.322721	4.7903866	2.863735	2.634242	3.093228	2.704792	4.79038666
RES-59; Parallel, 12-ESA, AR in Hab B, Lab B, & Lab D	3.322721	4.790387	3.322721	3.83904686	2.863735	2.634242	3.093228	2.704792	4.79038666
RES-60; Parallel, 12-JEM, AR in Hab B, Lab B, & Lab D	3.609554	3.322721	4.560894	3.32272078	3.035888	2.749055	3.322721	2.775343	4.56089354

Research Configuration Racetrack Ventilation

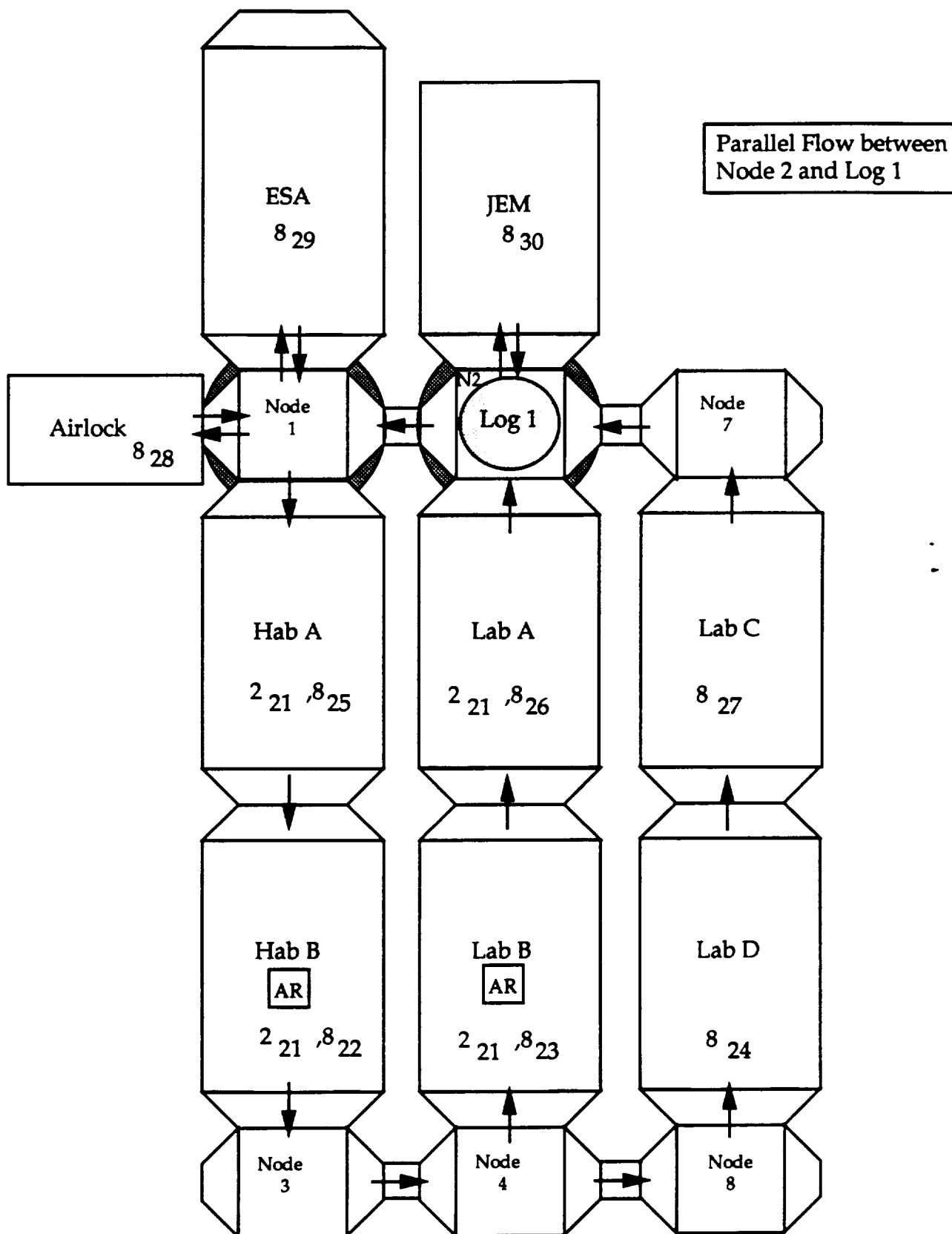


Research Configuration

Parallel Ventilation

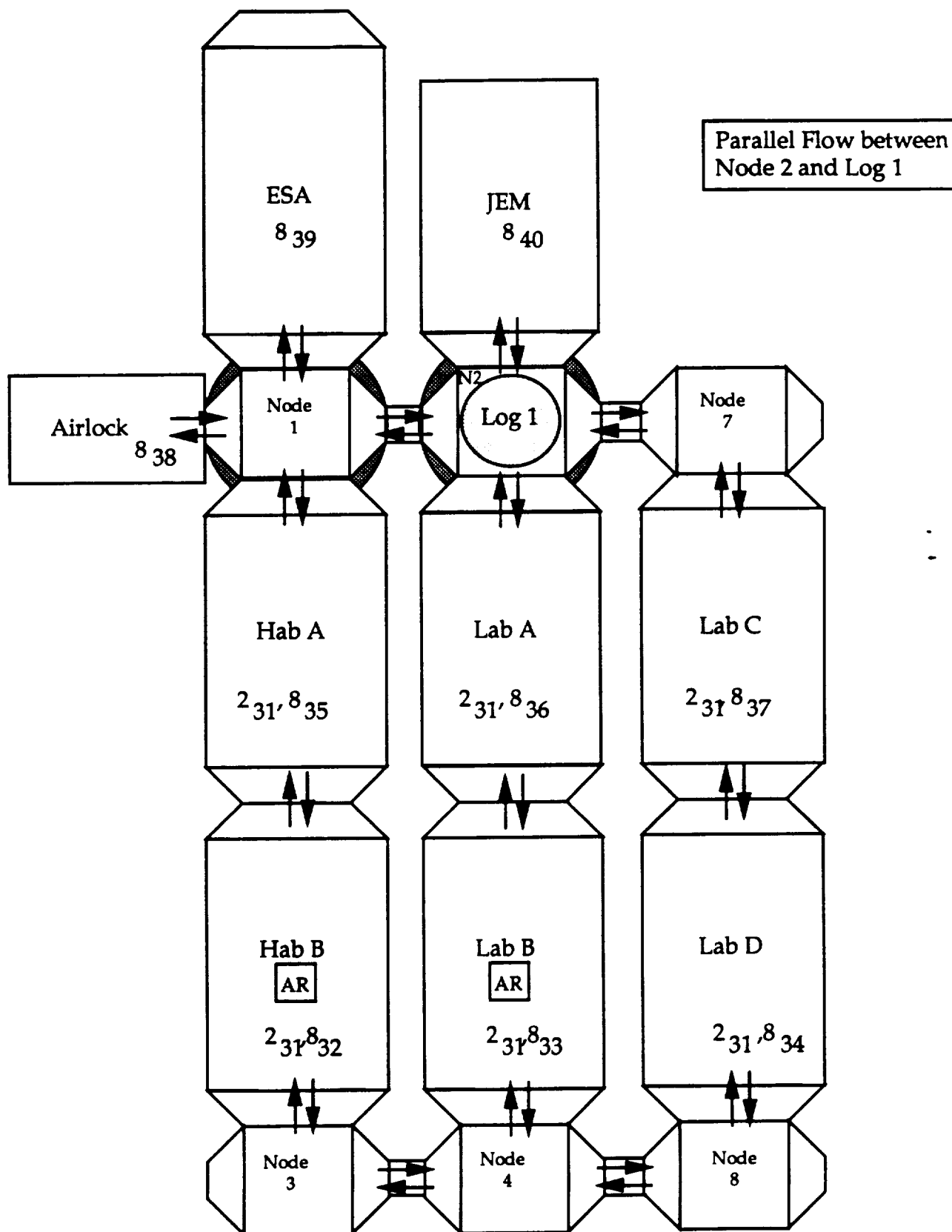


Research Configuration Racetrack Ventilation

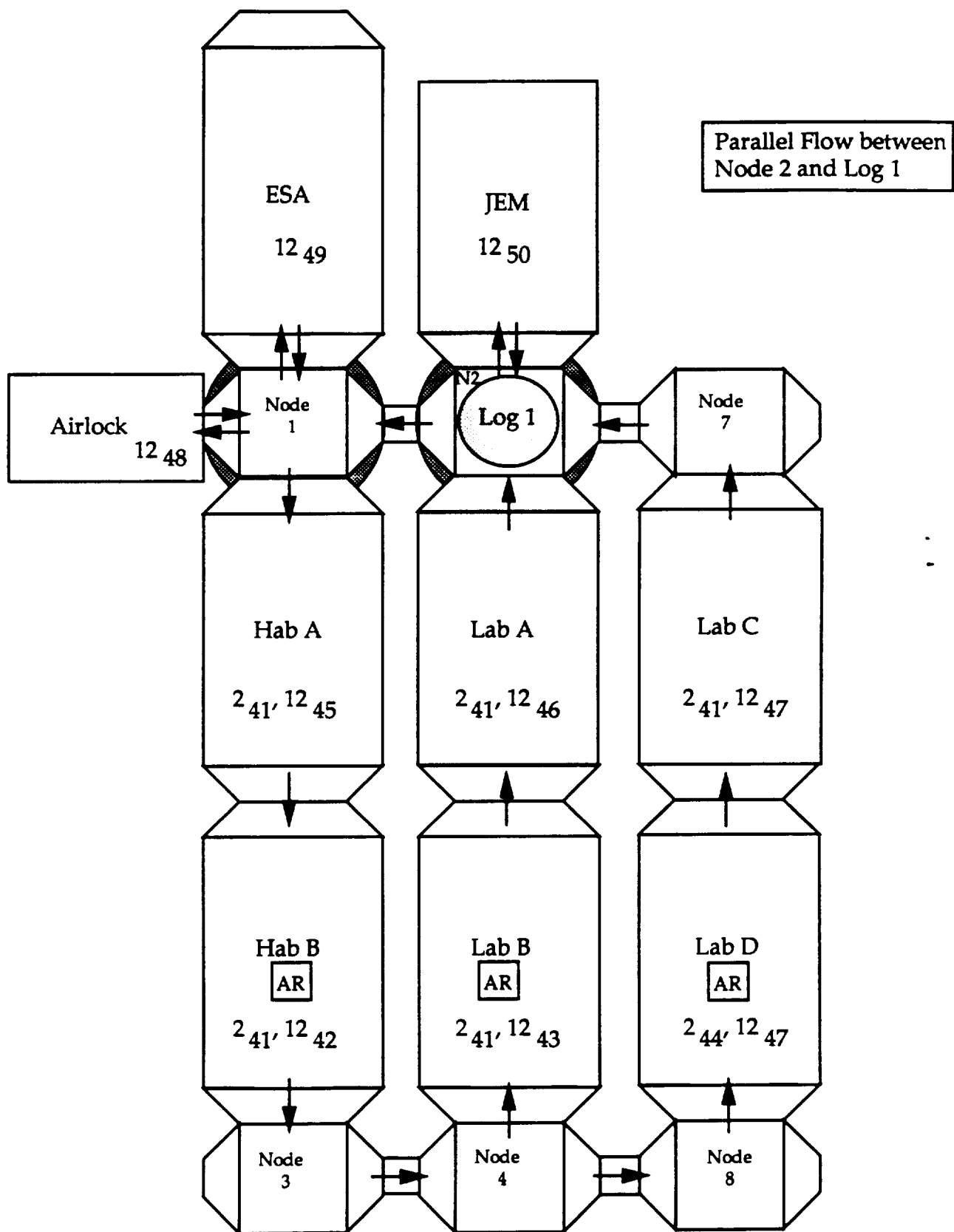


Research Configuration

Parallel Ventilation

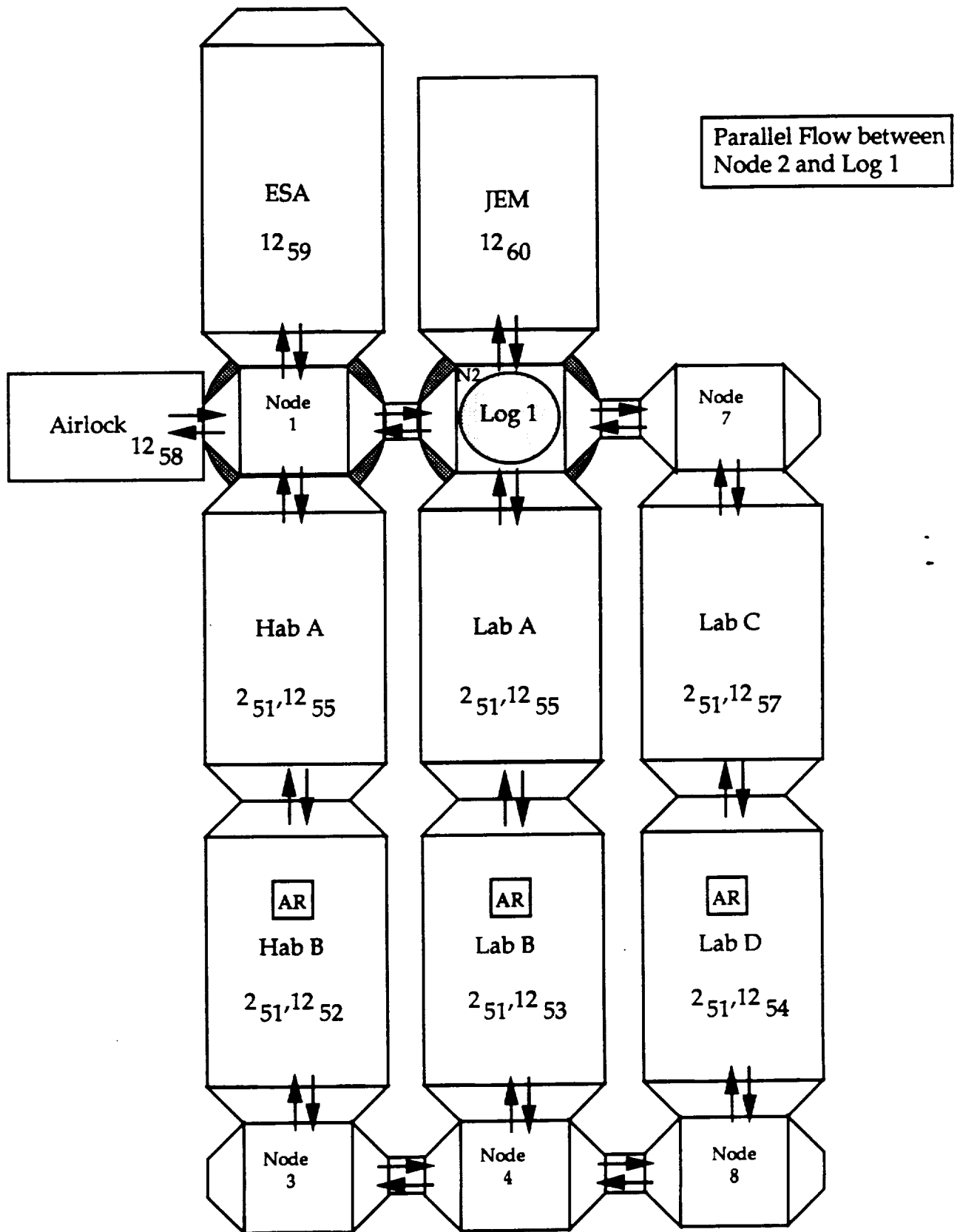


Research Configuration Racetrack Ventilation

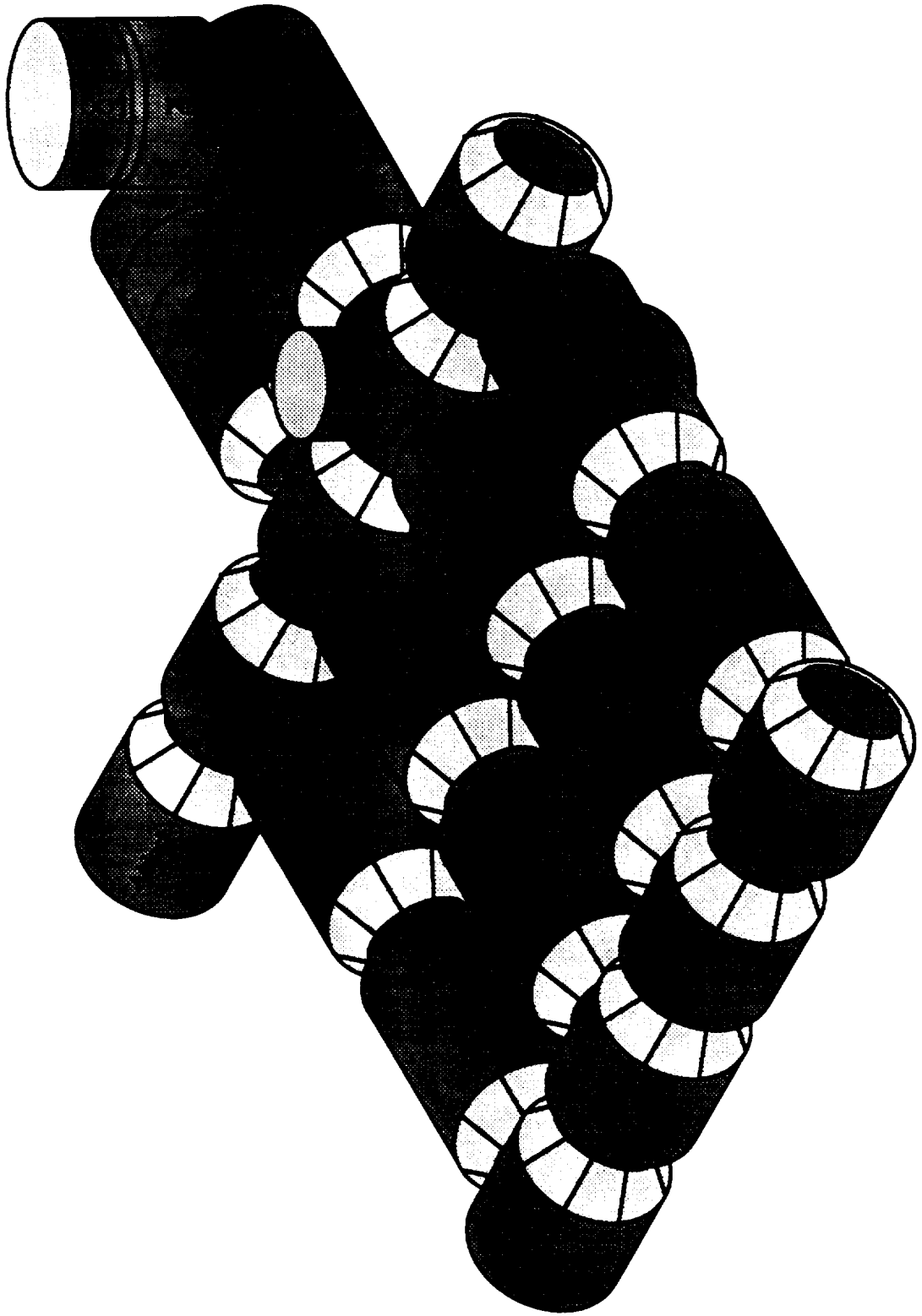


Research Configuration

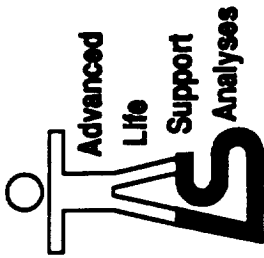
Parallel Ventilation



Research/Transportation Node Configuration



Research/Transportation Node Configuration Analysis of Trade Study Results



- With 16 crew and 4 ARs operating, the maximum degraded atmosphere limit is only exceeded with a racetrack configuration and all 16 crew in the ESA module.
- The parallel ventilation path generally provides significantly lower CO₂ concentrations than the corresponding racetrack ventilation path.

Results from Analysis of the Research/Transportation Node Configuration (page 1)

Description	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4
R&T-1; Racetrack, 16-Even, ARs in Hab B & D, and Lab B & D	5.568	5.727	1.586	1.428	6.044	3.172	2.863	1.432
R&T-2; Racetrack, 16-Hab A, ARs in Hab B & D, and Lab B & D	5.868	5.868	1.317	1.317	5.268	2.634	2.934	1.467
R&T-3; Racetrack, 16-Hab B, ARs in Hab B & D, and Lab B & D	5.268	6.537	1.467	1.467	5.868	2.934	3.268	1.634
R&T-4; Racetrack, 16-Hab C, ARs in Hab B & D, and Lab B & D	5.868	5.868	1.317	1.317	6.537	2.634	2.934	1.467
R&T-5; Racetrack, 16-Hab D, ARs in Hab B & D, and Lab B & D	5.268	5.268	1.182	1.182	5.868	2.365	2.634	1.317
R&T-6; Racetrack, 16-Lab A, ARs in Hab B & D, and Lab B & D	5.868	5.868	2.585	1.317	6.537	3.903	2.934	1.467
R&T-7; Racetrack, 16-Lab B, ARs in Hab B & D, and Lab B & D	5.268	5.268	2.321	2.321	5.868	3.503	2.634	1.317
R&T-8; Racetrack, 16-Lab C, ARs in Hab B & D, and Lab B & D	5.868	5.868	1.317	1.317	6.537	3.903	2.934	1.467
R&T-9; Racetrack, 16-Lab D, ARs in Hab B & D, and Lab B & D	5.268	5.268	1.182	1.182	5.868	3.503	2.634	1.317
R&T-10; Racetrack, 16-Airlock, ARs in Hab B & D, and Lab B & D	5.868	5.868	1.317	1.317	6.537	2.634	2.934	1.467
R&T-11; Racetrack, 16-ESA, ARs in Hab B & D, and Lab B & D	5.868	5.868	1.317	1.317	6.537	2.634	2.934	1.467
R&T-12; Racetrack, 16-JEM, ARs in Hab B & D, and Lab B & D	5.868	5.868	1.317	1.317	6.537	3.903	2.934	1.467
R&T-13; Parallel, 16-Even, ARs in Hab B & D, and Lab B & D	2.798	2.896	2.917	2.780	2.860	2.895	2.835	2.801
R&T-14; Parallel, 16-Hab A, ARs in Hab B & D, and Lab B & D	3.623	3.250	2.668	2.506	3.140	2.830	2.876	2.630
R&T-15; Parallel, 16-Hab B, ARs in Hab B & D, and Lab B & D	3.250	3.882	2.717	2.633	2.988	2.800	3.245	2.849
R&T-16; Parallel, 16-Hab C, ARs in Hab B & D, and Lab B & D	2.796	2.839	2.633	2.485	3.071	2.782	2.882	2.619
R&T-17; Parallel, 16-Hab D, ARs in Hab B & D, and Lab B & D	2.623	2.764	2.488	2.395	2.781	2.582	2.905	2.573
R&T-18; Parallel, 16-Lab A, ARs in Hab B & D, and Lab B & D	2.668	2.717	3.922	3.252	2.923	3.323	2.765	2.953
R&T-19; Parallel, 16-Lab B, ARs in Hab B & D, and Lab B & D	2.506	2.633	3.252	3.590	2.665	2.914	2.760	3.069
R&T-20; Parallel, 16-Lab C, ARs in Hab B & D, and Lab B & D	2.533	2.593	2.926	2.735	2.761	3.118	2.654	2.855
R&T-21; Parallel, 16-Lab D, ARs in Hab B & D, and Lab B & D	2.384	2.489	2.728	2.645	2.550	2.811	2.595	2.864
R&T-22; Parallel, 16-Airlock, ARs in Hab B & D, and Lab B & D	2.384	2.489	2.728	2.645	2.550	2.811	2.595	2.864
R&T-23; Parallel, 16-ESA, ARs in Hab B & D, and Lab B & D	3.140	2.988	2.923	2.665	3.650	3.181	2.835	2.710
R&T-24; Parallel, 16-JEM, ARs in Hab B & D, and Lab B & D	2.830	2.800	3.323	2.914	3.181	3.733	2.771	2.836

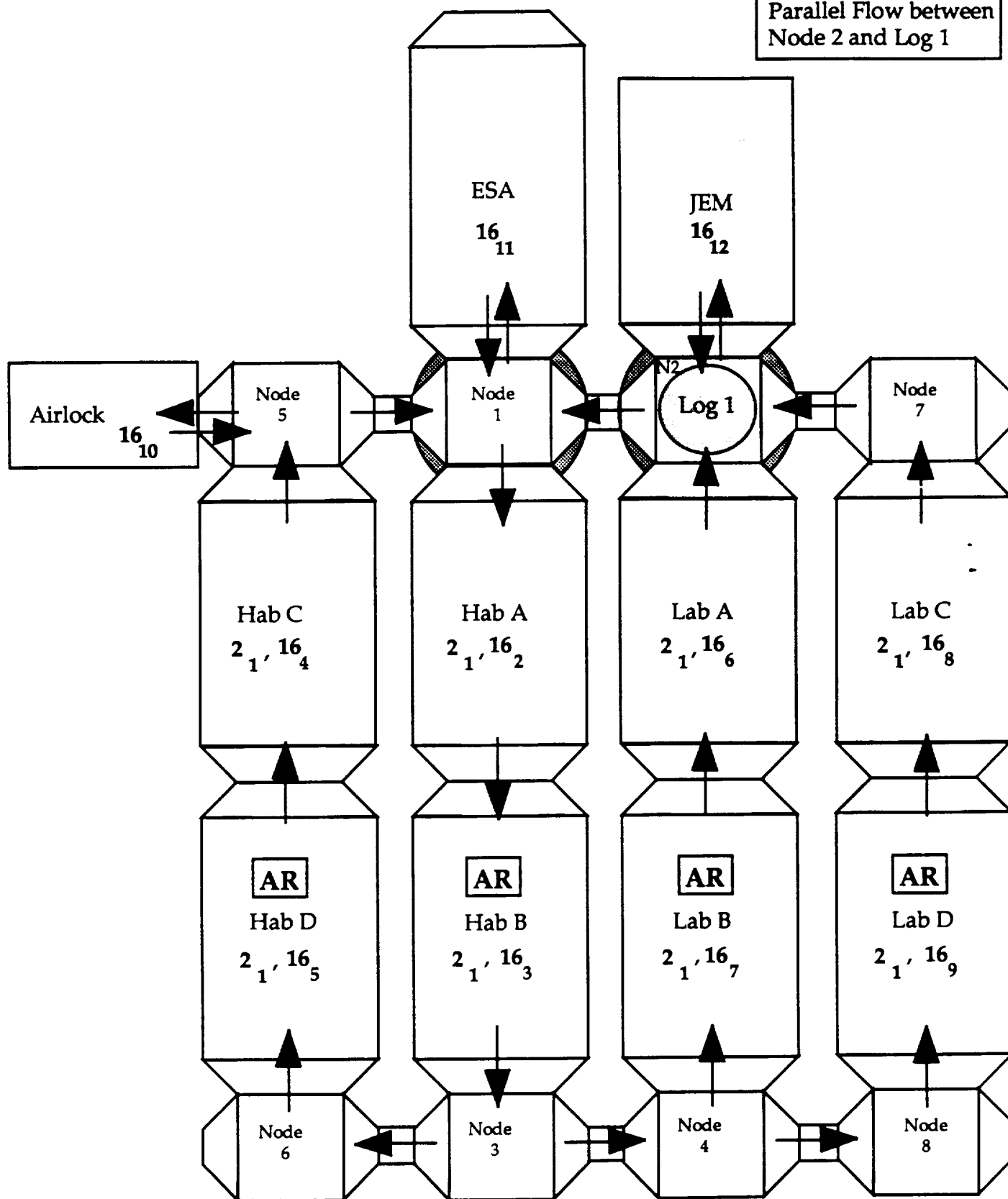
Results from Analysis of the Research/Transportation Node Configuration (page 2)

Description	Log 1	ESA	JEM	Airlock	Hab C	Hab D	Node 5	Node 6	Node 7	Node 8	Lab C	Lab D	Maximum
R&T-1;	3.172	6.044	3.172	2.871	2.871	2.713	2.871	2.863	1.586	1.432	1.586	1.428	6.044
R&T-2;	2.634	5.268	2.634	2.634	2.634	2.634	2.634	2.934	1.317	1.467	1.317	1.317	5.868
R&T-3;	2.934	5.868	2.934	2.934	2.934	2.934	2.934	3.268	1.467	1.634	1.467	1.467	6.537
R&T-4;	2.634	6.537	2.634	3.903	3.903	2.634	3.903	2.934	1.317	1.467	1.317	1.317	6.537
R&T-5;	2.365	5.868	2.365	3.503	3.503	3.503	3.503	2.634	1.182	1.317	1.182	1.182	5.868
R&T-6;	3.903	6.537	3.903	2.634	2.634	2.634	2.634	2.934	1.317	1.467	1.317	1.317	6.537
R&T-7;	3.503	5.868	3.503	2.365	2.365	2.365	2.365	2.634	1.182	1.317	1.182	1.182	5.868
R&T-8;	3.903	6.537	3.903	2.634	2.634	2.634	2.634	2.934	2.585	1.467	2.585	1.317	6.537
R&T-9;	3.503	5.868	3.503	2.365	2.365	2.365	2.365	2.634	2.321	1.317	2.321	2.321	5.868
R&T-10;	2.634	6.537	2.634	5.171	2.634	2.634	3.903	2.934	1.317	1.467	1.317	1.317	6.537
R&T-11;	2.634	7.805	2.634	2.634	2.634	2.634	2.634	2.934	1.317	1.467	1.317	1.317	7.805
R&T-12;	3.903	6.537	5.171	2.634	2.634	2.634	2.634	2.934	1.317	1.467	1.317	1.317	6.537
R&T-13;	2.895	2.860	2.895	2.887	2.914	2.782	2.887	2.809	2.908	2.789	2.922	2.777	2.922
R&T-14;	2.830	3.140	2.830	2.968	2.796	2.623	2.968	2.750	2.681	2.507	2.533	2.384	3.623
R&T-15;	2.800	2.988	2.800	2.913	2.839	2.764	2.913	3.005	2.697	2.669	2.593	2.489	3.882
R&T-16;	2.782	3.071	2.782	3.635	4.199	3.495	3.635	3.188	2.642	2.490	2.502	2.361	4.199
R&T-17;	2.582	2.781	2.582	3.138	3.495	3.851	3.138	3.378	2.477	2.420	2.372	2.267	3.851
R&T-18;	3.323	2.923	3.323	2.778	2.633	2.488	2.778	2.627	3.125	2.840	2.926	2.728	3.922
R&T-19;	2.914	2.665	2.914	2.575	2.485	2.395	2.575	2.577	2.824	2.857	2.735	2.645	3.590
R&T-20;	3.118	2.761	3.118	2.631	2.502	2.372	2.631	2.513	3.667	3.176	4.216	3.497	4.216
R&T-21;	2.811	2.550	2.811	2.456	2.361	2.267	2.456	2.431	3.154	3.352	3.497	3.840	3.840
R&T-22;	2.811	2.550	2.811	2.456	2.361	2.267	2.456	2.431	3.154	3.352	3.497	3.840	3.840
R&T-23;	3.181	4.919	3.181	3.361	3.071	2.781	3.361	2.808	2.971	2.630	2.761	2.550	4.919
R&T-24;	3.733	3.181	5.001	2.982	2.782	2.582	2.982	2.677	3.425	2.823	3.118	2.811	5.001

Research/Transportation Node Configuration

Racetrack Ventilation

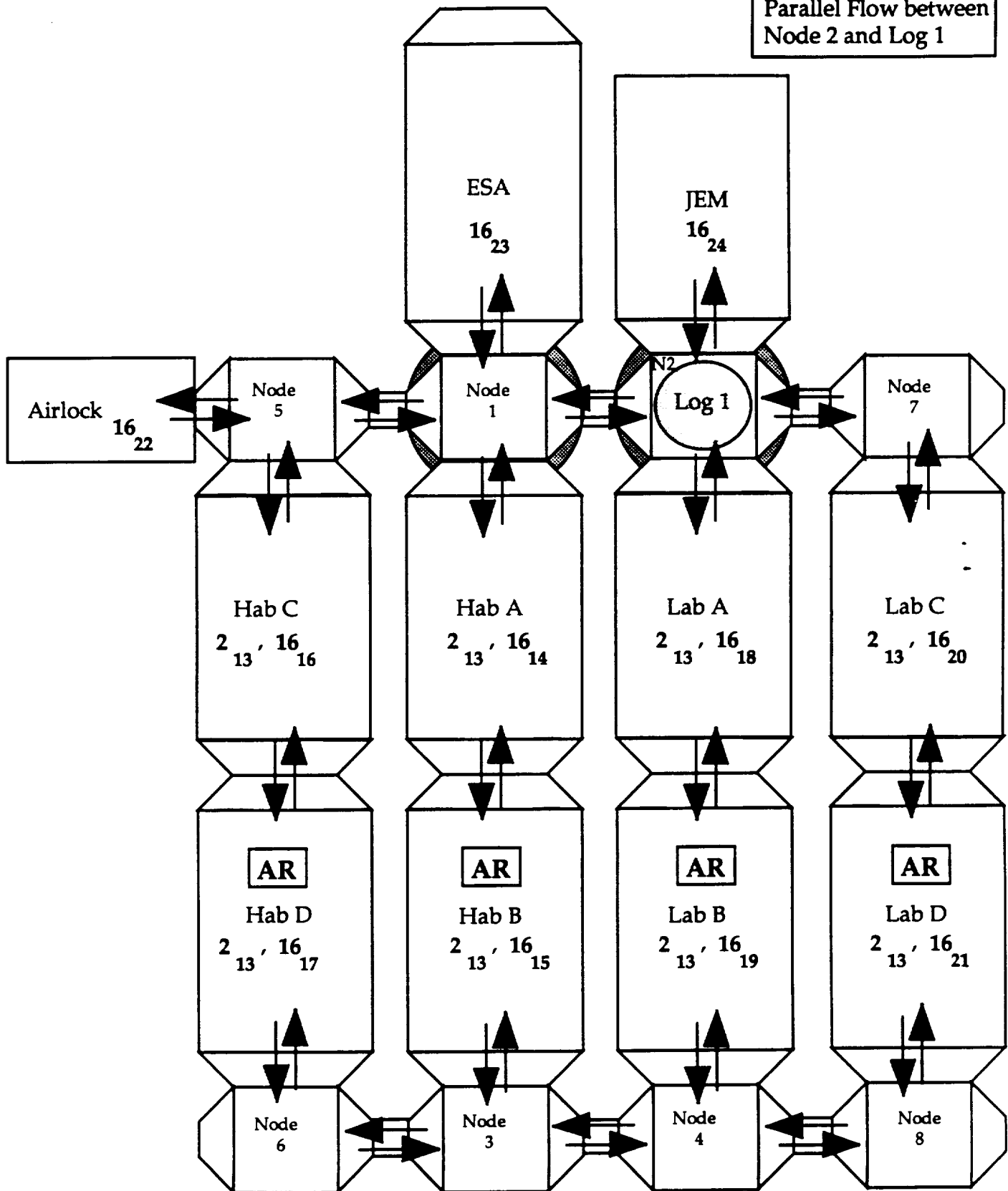
Parallel Flow between
Node 2 and Log 1



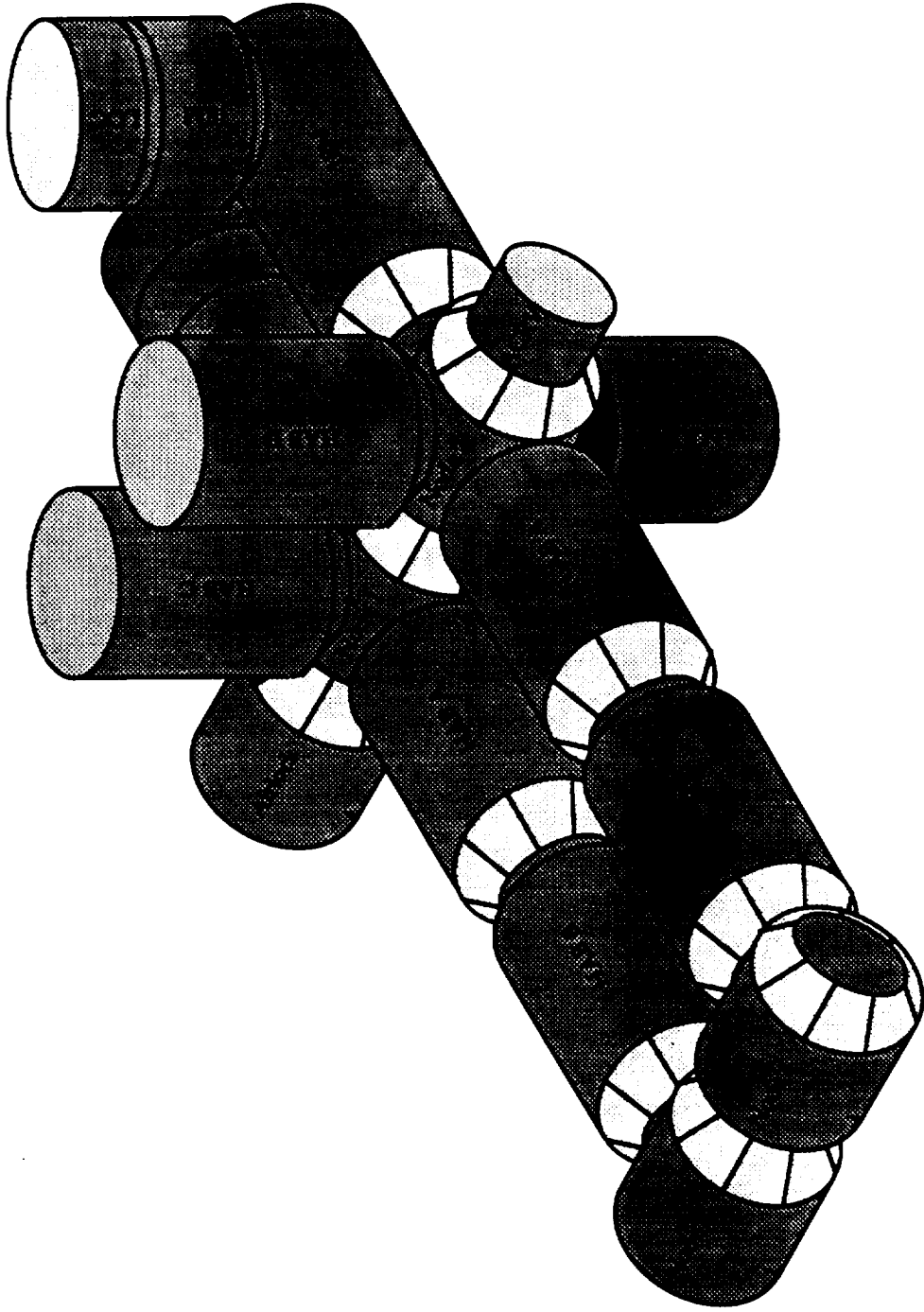
Research/Transportation Node Configuration

Parallel Ventilation

Parallel Flow between
Node 2 and Log 1

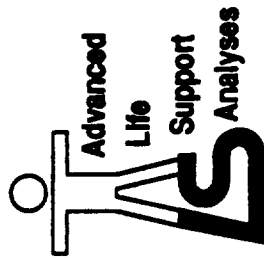


FMCC Configuration



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FMCC Configuration Analysis of Trade Study Results



- With 4 ARs operating and 12 crew, adequate ventilation to remain below the operational limit is provided in almost all cases. The operational limit is only exceeded in the cases where all 12 crew are concentrated in the JEM and ESA modules.

Results from the Analysis of the FMCC Configuration (page 1)

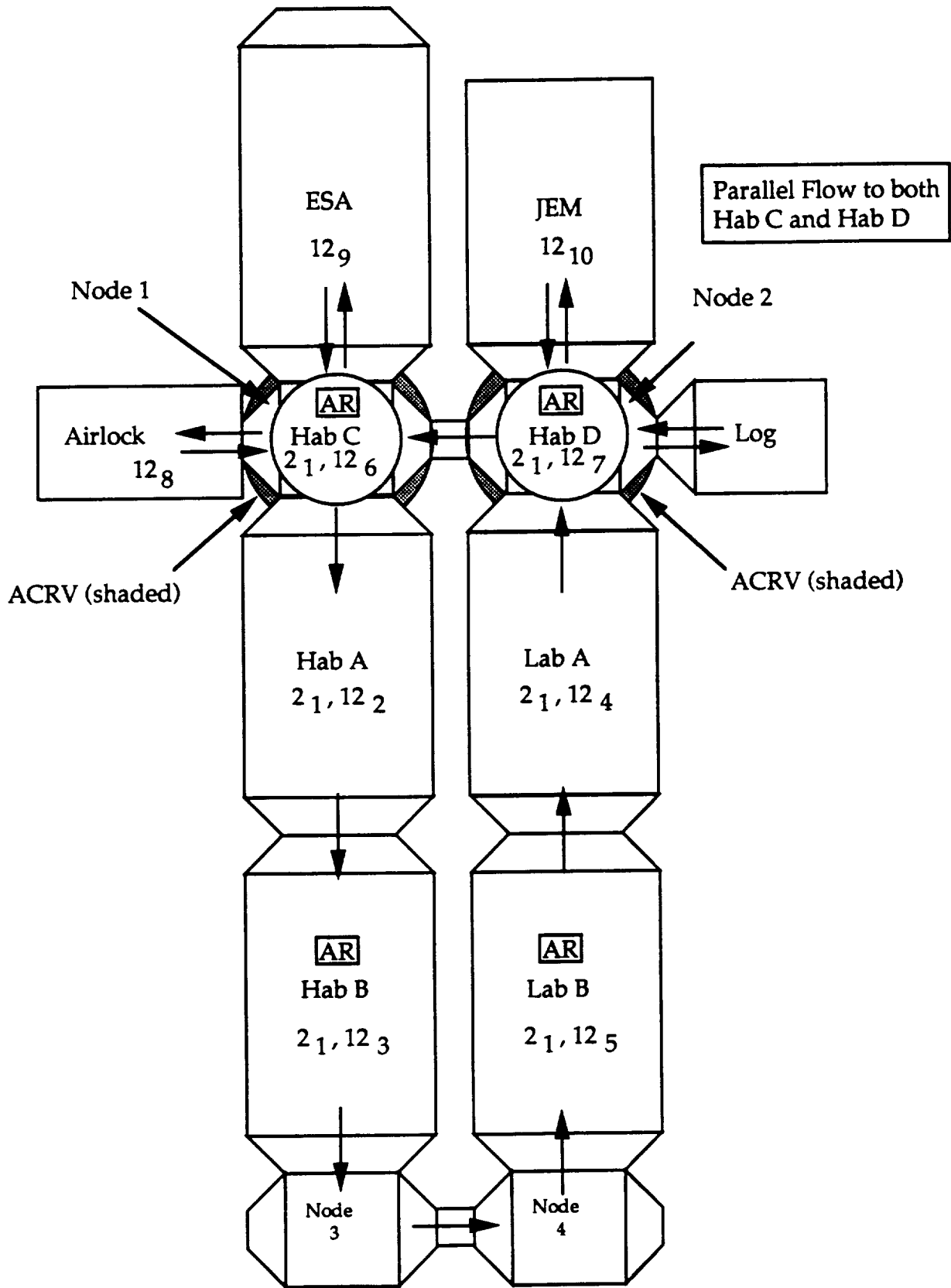
Description	Hab A	Hab B	Lab A	Lab B
FMCC-1; Racetrack, 12-Even, ARs in Hab's B, C, and D and Lab B	2.251	2.163	2.243	2.084
FMCC-2; Racetrack, 12-Hab A, ARs in Hab's B, C, and D and Lab B	2.826	2.537	2.278	2.278
FMCC-3; Racetrack, 12-Hab B, ARs in Hab's B, C, and D and Lab B	1.875	2.537	2.278	2.278
FMCC-4; Racetrack, 12-Lab A, ARs in Hab's B, C, and D and Lab B	2.326	2.088	2.826	1.875
FMCC-5; Racetrack, 12-Lab B, ARs in Hab's B, C, and D and Lab B	2.088	1.875	2.537	2.537
FMCC-6; Racetrack, 12-Hab C, ARs in Hab's B, C, and D and Lab B	2.302	2.066	1.855	1.855
FMCC-7; Racetrack, 12-Hab D, ARs in Hab's B, C, and D and Lab B	2.088	1.875	1.683	1.683
FMCC-8; Racetrack, 12-Airlock, ARs in Hab's B, C, and D and Lab B	2.564	2.302	2.066	2.066
FMCC-9; Racetrack, 12-ESA, ARs in Hab's B, C, and D and Lab B	2.564	2.302	2.066	2.066
FMCC-10; Racetrack, 12-JEM, ARs in Hab's B, C, and D and Lab B	2.326	2.088	1.875	1.875
FMCC-11; Parallel, 12-Even, ARs in Hab's B, C, and D and Lab B	2.205	2.122	2.205	2.122
FMCC-12; Parallel, 12-Hab A, ARs in Hab's B, C, and D and Lab B	2.865	2.429	2.013	1.950
FMCC-13; Parallel, 12-Hab B, ARs in Hab's B, C, and D and Lab B	2.429	2.794	1.950	1.991
FMCC-14; Parallel, 12-Lab A, ARs in Hab's B, C, and D and Lab B	2.013	1.950	2.865	2.429
FMCC-15; Parallel, 12-Lab B, ARs in Hab's B, C, and D and Lab B	1.950	1.991	2.429	2.794
FMCC-16; Parallel, 12-Hab C, ARs in Hab's B, C, and D and Lab B	2.110	1.853	1.863	1.714
FMCC-17; Parallel, 12-Hab D, ARs in Hab's B, C, and D and Lab B	1.863	1.714	2.110	1.853
FMCC-18; Parallel, 12-Airlock, ARs in Hab's B, C, and D and Lab B	2.350	2.064	2.075	1.909
FMCC-19; Parallel, 12-ESA, ARs in Hab's B, C, and D and Lab B	2.350	2.064	2.075	1.909
FMCC-20; Parallel, 12-JEM, ARs in Hab's B, C, and D and Lab B	2.075	1.909	2.350	2.064

Results from the Analysis of the FMCC Configuration (page 2)

Description	Node 1	Node 2	Node 3	Node 4	Log 1	ESA	IEM	Airlock	Hab C	Hab D	Maximum
FMCC-1;	2.092	2.164	2.163	2.163	2.164	2.092	2.164	2.092	2.021	2.085	2.251
FMCC-2;	1.875	2.066	2.537	2.537	2.066	1.875	2.066	1.875	1.683	1.855	2.826
FMCC-3;	1.875	2.066	2.537	2.537	2.066	1.875	2.066	1.875	1.683	1.855	2.537
FMCC-4;	2.326	2.564	2.088	2.088	2.564	2.326	2.564	2.326	2.088	2.302	2.826
FMCC-5;	2.088	2.302	1.875	1.875	2.302	2.088	2.302	2.088	1.875	2.066	2.537
FMCC-6;	2.302	1.683	2.066	2.066	1.683	2.302	1.683	2.302	2.920	1.511	2.920
FMCC-7;	2.088	2.302	1.875	1.875	2.302	2.088	2.302	2.088	1.875	2.920	2.920
FMCC-8;	2.564	1.875	2.302	2.302	1.875	2.564	1.875	3.515	2.302	1.683	3.515
FMCC-9;	2.564	1.875	2.302	2.302	1.875	3.515	1.875	2.564	2.302	1.683	3.515
FMCC-10;	2.326	2.564	2.088	2.088	2.564	2.326	3.515	2.326	2.088	2.302	3.515
FMCC-11;	2.130	2.130	2.122	2.122	2.130	2.130	2.130	2.130	2.054	2.054	2.205
FMCC-12;	2.350	2.075	2.269	2.110	2.075	2.350	2.075	2.350	2.110	1.863	2.865
FMCC-13;	2.064	1.909	2.527	2.259	1.909	2.064	1.909	2.064	1.853	1.714	2.794
FMCC-14;	2.075	2.350	2.110	2.269	2.350	2.075	2.350	2.075	1.863	2.110	2.865
FMCC-15;	1.909	2.064	2.259	2.527	2.064	1.909	2.064	1.909	1.714	1.853	2.794
FMCC-16;	2.367	2.012	1.806	1.760	2.012	2.367	2.012	2.367	2.979	1.806	2.979
FMCC-17;	2.012	2.367	1.760	1.806	2.367	2.012	2.367	2.012	1.806	2.979	2.979
FMCC-18;	2.637	2.241	2.012	1.961	2.241	2.637	2.241	3.588	2.367	2.012	3.588
FMCC-19;	2.637	2.241	2.012	1.961	2.241	3.588	2.241	2.637	2.367	2.012	3.588
FMCC-20;	2.241	2.637	1.961	2.012	2.637	2.241	3.588	2.241	2.012	2.367	3.588

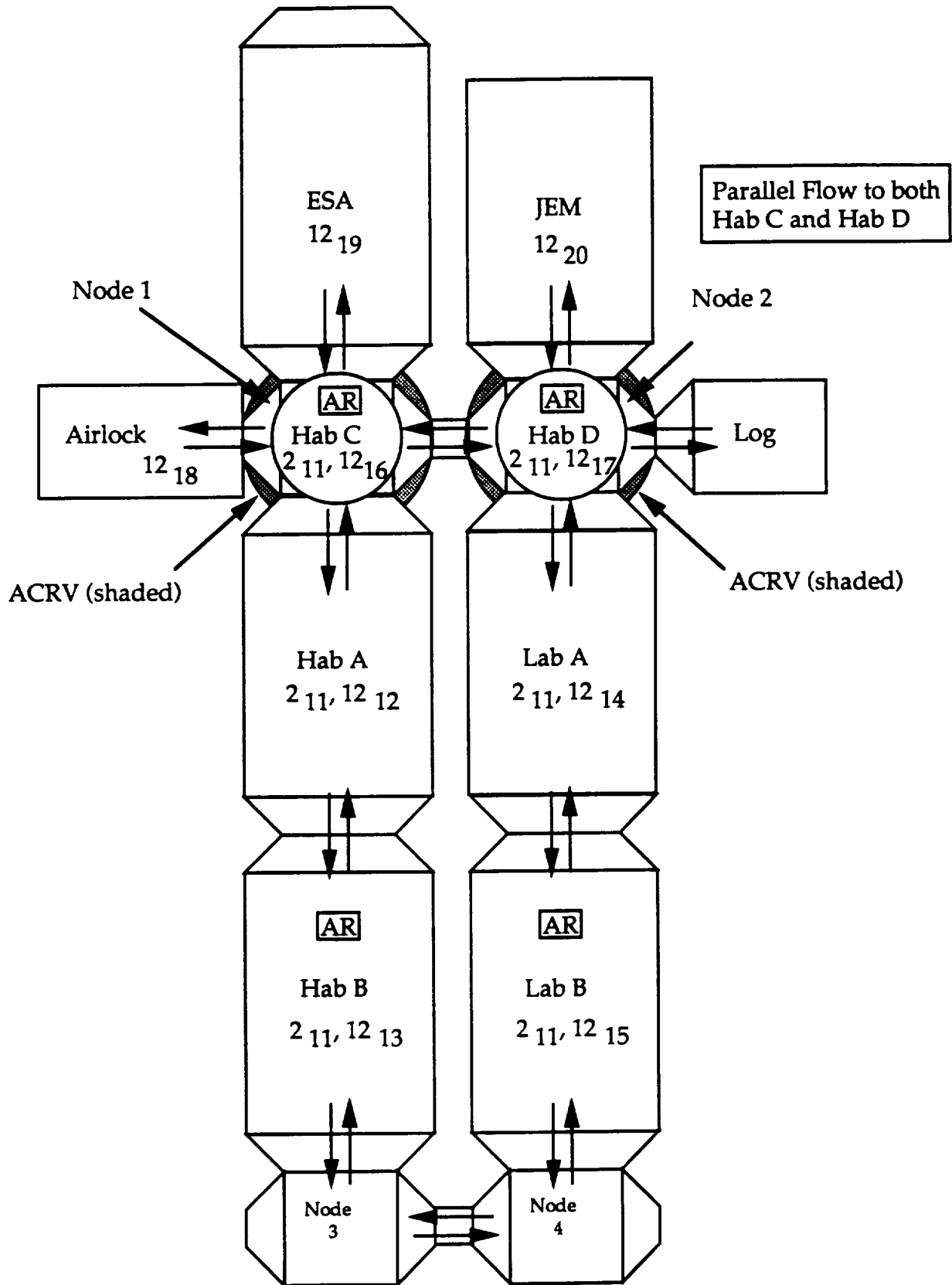
FMCC Configuration

Racetrack Ventilation

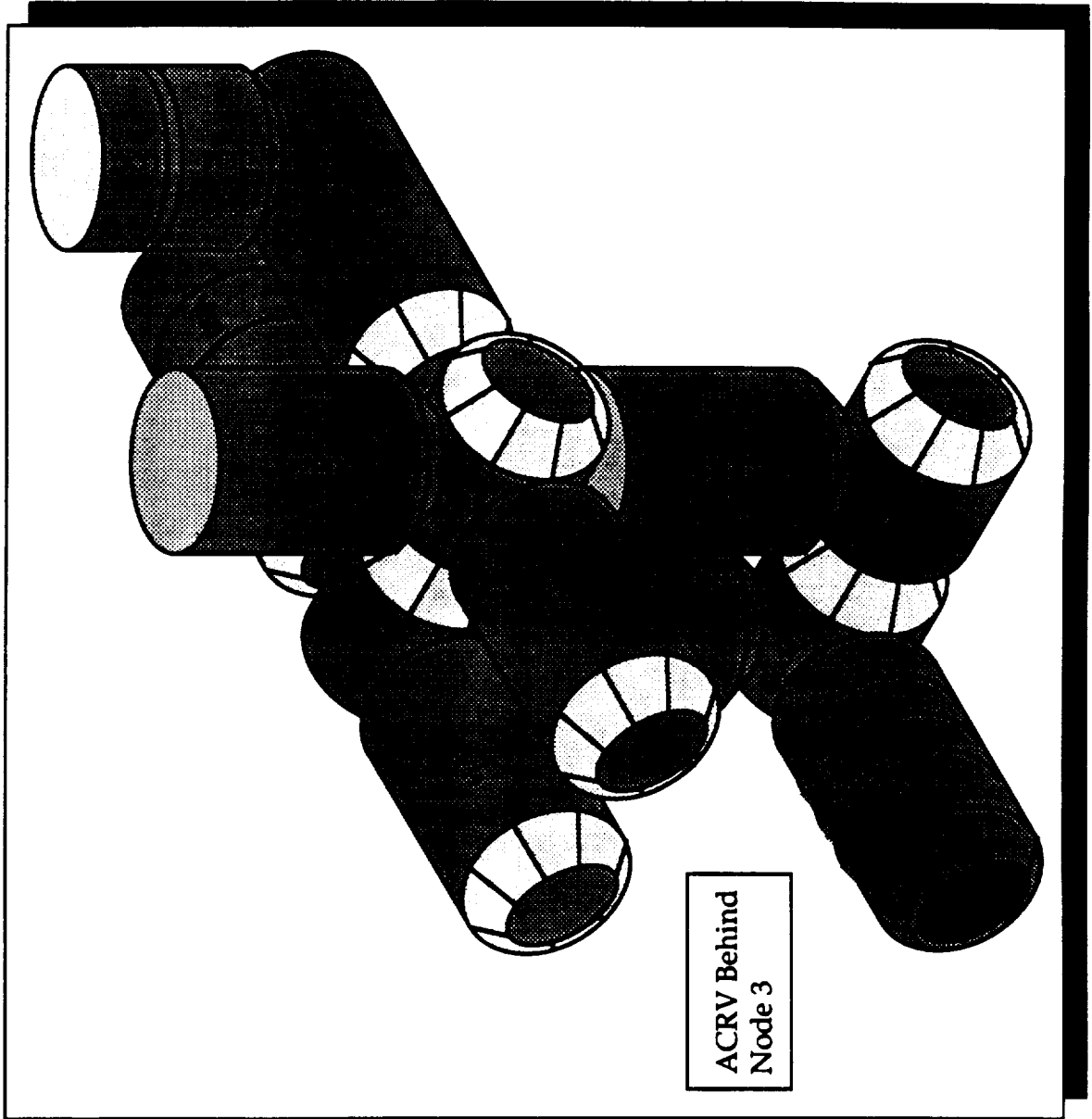


FMCC Configuration

Parallel Ventilation



Option C Configuration



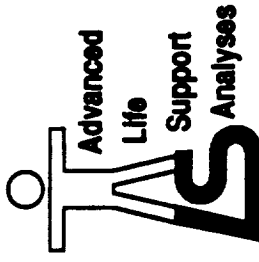
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Option-C Configuration Trade Study Results

Description	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4	Log 1	ESA	JEM	Airlock	Max
OPT-C-1; Racetrack, Even, ARs in Hab B and Lab B	3.185	2.859	3.026	2.709	3.026	2.868	2.859	2.859	2.859	3.026	2.868	2.868	3.185
OPT-C-2; Racetrack, 8-Hab A, ARs in Hab B and Lab B	3.903	2.934	2.634	2.634	3.268	2.634	2.934	2.934	2.934	3.268	2.634	2.634	3.903
OPT-C-3; Racetrack, 8-Hab B, ARs in Hab B and Lab B	2.634	2.934	2.634	2.634	2.634	2.634	2.934	2.934	2.934	2.634	2.634	2.634	2.934
OPT-C-4; Racetrack, 8-Lab A, ARs in Hab B and Lab B	3.268	2.934	3.903	2.634	3.268	3.268	2.934	2.934	2.934	3.268	3.268	3.268	3.903
OPT-C-5; Racetrack, 8-Lab B, ARs in Hab B and Lab B	2.934	2.634	2.934	2.934	2.934	2.934	2.634	2.634	2.634	2.934	2.934	2.934	2.934
OPT-C-6; Racetrack, 8-ESA, ARs in Hab B and Lab B	3.268	2.934	2.634	2.634	3.268	2.634	2.934	2.934	2.934	3.903	2.634	2.634	3.903
OPT-C-7; Racetrack, 8-JEM, ARs in Hab B and Lab B	3.268	2.934	3.268	2.634	3.268	3.268	2.934	2.934	2.934	3.268	3.903	3.268	3.903
OPT-C-8; Parallel, 8-Even, ARs in Hab B and Lab B	3.101	2.784	3.101	2.784	2.943	2.943	2.784	2.784	2.784	2.943	2.943	2.943	3.101
OPT-C-9; Parallel, 8-Hab A, ARs in Hab B and Lab B	3.865	2.857	2.971	2.711	3.231	2.971	2.808	2.760	2.808	3.231	2.971	2.971	3.865
OPT-C-10; Parallel, 8-Hab B, ARs in Hab B and Lab B	2.857	3.003	2.711	2.565	2.857	2.711	2.857	2.711	2.857	2.857	2.711	2.711	3.003
OPT-C-11; Parallel, 8-Lab A, ARs in Hab B and Lab B	2.971	2.711	3.865	2.857	2.971	3.231	2.760	2.808	2.760	2.971	3.231	3.231	3.865
OPT-C-12; Parallel, 8-Lab B, ARs in Hab B and Lab B	2.711	2.565	2.857	3.003	2.711	2.857	2.711	2.857	2.711	2.711	2.857	2.857	3.003
OPT-C-13; Parallel, 8-ESA, ARs in Hab B and Lab B	3.231	2.857	2.971	2.711	3.231	2.971	2.808	2.760	2.808	3.865	2.971	2.971	3.865
OPT-C-14; Parallel, 8-JEM, ARs in Hab B and Lab B	2.971	2.711	3.231	2.857	2.971	3.231	2.760	2.808	2.760	2.971	3.865	3.231	3.865

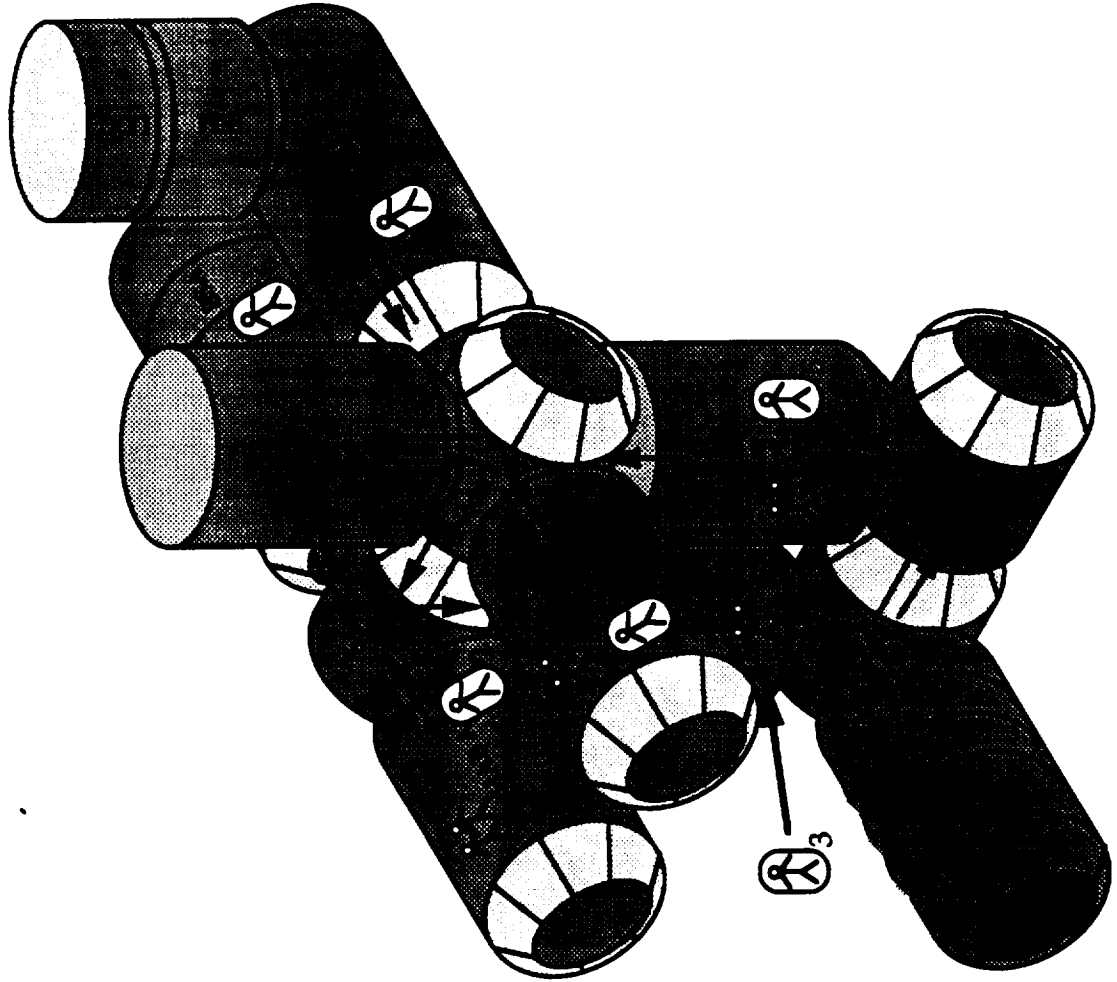
EMCC Option C Configuration Analysis of Trade Study Results




- With 8 crew and two operating ARs , the operational limit is only exceeded in a few cases.

Option C Configuration

Racetrack

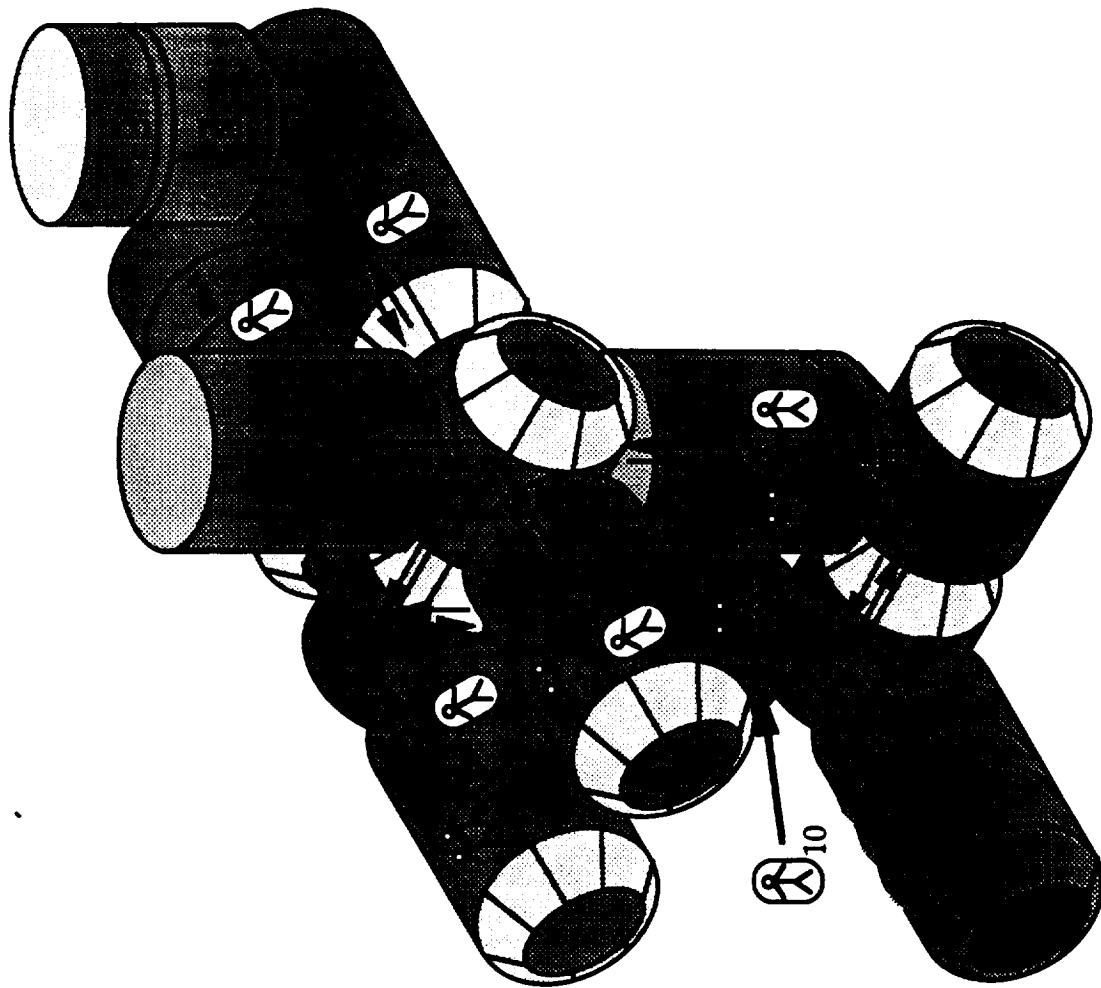



 = 8 crew

ACRV Behind
Node 3

Option C Configuration

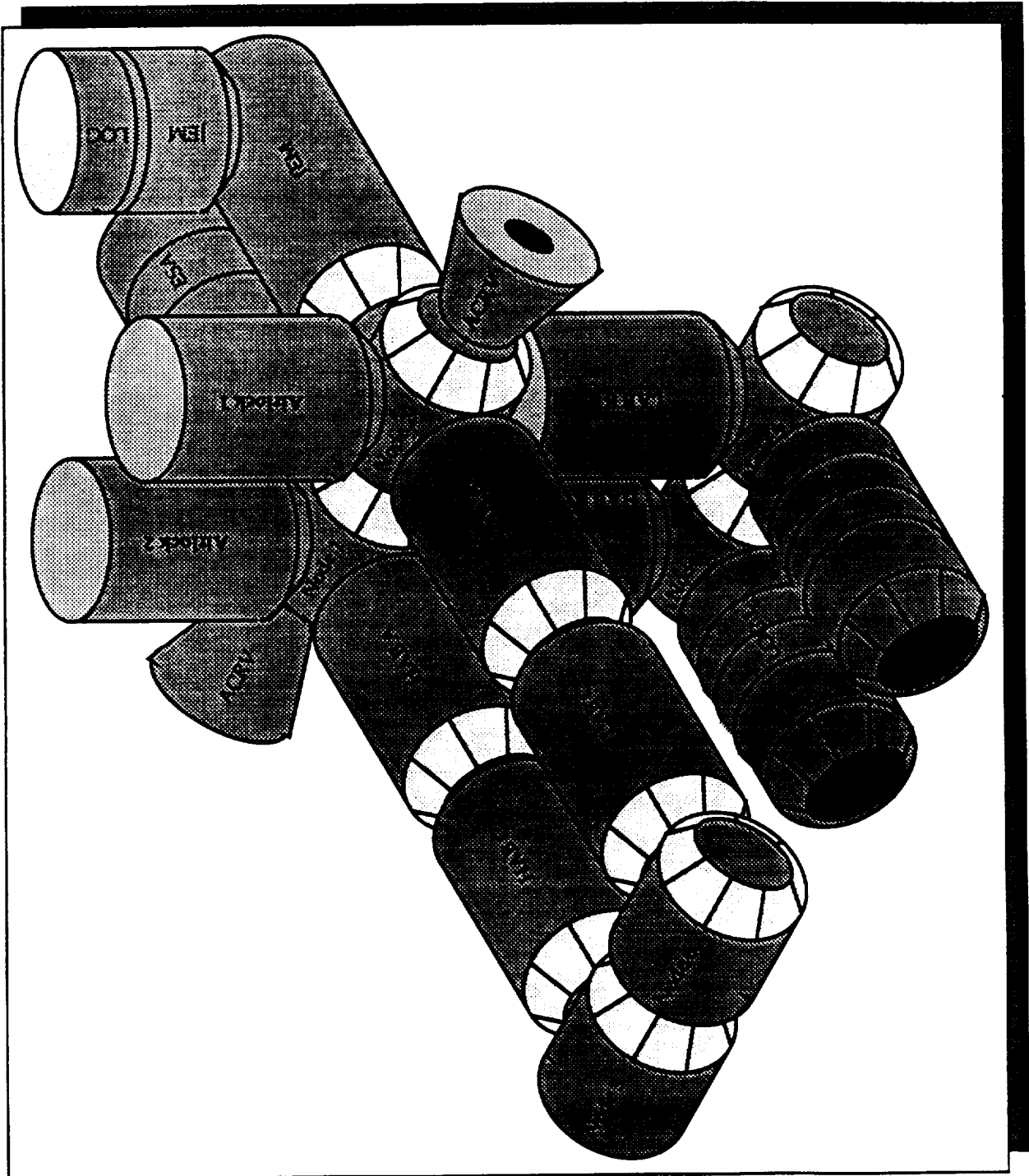
Parallel



 = 8 crew

ACRV Behind
Node 3

—



Growth Option A Configuration Trade Study Summary

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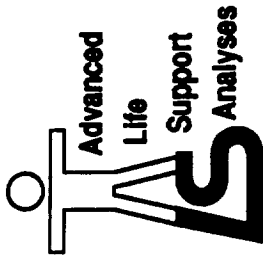
Growth Option A Trade Study Results

Description	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4
G-OPTA-1; Racetrack, 12-Even, AR's in Hab B, Lab B, & Lab A	2.99178	2.685861	3.11289	2.553563	2.833227	5.66455	2.685861	2.685861
G-OPTA-2; Racetrack, 12-Hab A, AR's in Hab B, Lab B, & Lab A	3.83369	2.587617	3.44168	2.323021	2.88235	5.764699	2.587617	2.587617
G-OPTA-3; Racetrack, 12-Hab B, AR's in Hab B, Lab B, & Lab A	2.58762	3.177083	2.32302	2.852212	2.587617	5.175233	3.177083	3.177083
G-OPTA-4; Racetrack, 12-Hab C, AR's in Hab B, Lab B, & Lab A	2.88235	2.587617	3.44168	2.323021	2.88235	5.764699	2.587617	2.587617
G-OPTA-5; Racetrack, 12-Lab A, AR's in Hab B, Lab B, & Lab A	2.88235	2.587617	3.44168	2.323021	2.88235	5.764699	2.587617	2.587617
G-OPTA-6; Racetrack, 12-Lab B, AR's in Hab B, Lab B, & Lab A	2.88235	2.587617	2.58762	3.177083	2.88235	5.764699	2.587617	2.587617
G-OPTA-7; Racetrack, 12-Lab C, AR's in Hab B, Lab B, & Lab A	2.88235	2.587617	3.44168	2.323021	2.88235	5.764699	2.587617	2.587617
G-OPTA-8; Racetrack, 12-ESA, AR's in Hab B, Lab B, & Lab A	3.21065	2.88235	2.88235	2.587617	3.210653	5.469966	2.88235	2.88235
G-OPTA-9; Racetrack, 12-JEM, AR's in Hab B, Lab B, & Lab A	3.21065	2.88235	2.88235	2.587617	3.210653	6.421306	2.88235	2.88235
G-OPTA-10; Parallel, 12-Even, AR's in Hab B, Lab B, & Lab A	3.18533	2.756039	2.88869	2.707586	2.927549	2.841276	2.739888	2.723737
G-OPTA-11; Parallel, 12-Hab A, AR's in Hab B, Lab B, & Lab A	3.96905	2.859075	2.82159	2.671651	3.247202	2.913481	2.7966	2.734126
G-OPTA-12; Parallel, 12-Hab B, AR's in Hab B, Lab B, & Lab A	2.85907	3.286176	2.46577	2.600374	2.937736	2.667959	3.057575	2.828974
G-OPTA-13; Parallel, 12-Hab C, AR's in Hab B, Lab B, & Lab A	3.73956	2.780413	2.9246	2.6473	3.141477	2.90446	2.736042	2.691671
G-OPTA-14; Parallel, 12-Lab A, AR's in Hab B, Lab B, & Lab A	2.82159	2.465766	3.33665	2.549896	2.718577	2.868376	2.49381	2.521853
G-OPTA-15; Parallel, 12-Lab B, AR's in Hab B, Lab B, & Lab A	2.67165	2.600374	2.5499	3.202046	2.696002	2.815981	2.800931	3.001489
G-OPTA-16; Parallel, 12-Lab C, AR's in Hab B, Lab B, & Lab A	3.05108	2.544428	3.23364	2.574247	2.824302	2.877397	2.554368	2.564307
G-OPTA-17; Parallel, 12-ESA, AR's in Hab B, Lab B, & Lab A	3.2472	2.937736	2.71858	2.696002	3.352927	2.922502	2.857158	2.77658
G-OPTA-18; Parallel, 12-JEM, AR's in Hab B, Lab B, & Lab A	2.91348	2.667959	2.86838	2.815981	2.922502	3.186066	2.7173	2.766641

Growth Option A Trade Study Results (cont'd)

Description	Log 1	ESA	JEM	Airlock 1	Hab C	Lab C	Node 5	Node 6	Log 2	Airlock 2
G-OPTA-1	2.685861	2.833227	5.666455	5.6664549	3.150341	3.308897	3.150341	3.150341	2.685861	2.833227
G-OPTA-2	2.587617	2.88235	5.764699	5.7646992	3.833689	3.833689	3.833689	3.833689	2.587617	2.88235
G-OPTA-3	3.177083	2.587617	5.175233	5.1752333	2.587617	2.587617	2.587617	2.587617	3.177083	2.587617
G-OPTA-4	2.587617	2.88235	5.764699	5.7646992	3.833689	3.833689	3.833689	3.833689	2.587617	2.88235
G-OPTA-5	2.587617	2.88235	5.764699	5.7646992	2.88235	2.88235	2.88235	2.88235	2.587617	2.88235
G-OPTA-6	2.587617	2.88235	5.764699	5.7646992	2.88235	2.88235	2.88235	2.88235	2.587617	2.88235
G-OPTA-7	2.587617	2.88235	5.764699	5.7646992	2.88235	3.833689	2.88235	2.88235	2.587617	2.88235
G-OPTA-8	2.88235	4.161993	5.469966	5.4699663	3.210653	3.210653	3.210653	3.210653	2.88235	3.210653
G-OPTA-9	2.88235	3.210653	7.372646	6.421306	3.210653	3.210653	3.210653	3.210653	2.88235	3.210653
G-OPTA-10	2.739888	2.927549	2.841276	2.8412756	3.284562	3.106577	3.225234	3.165905	2.723737	2.927549
G-OPTA-11	2.7966	3.247202	2.913481	2.913481	3.739558	3.051082	3.510066	3.280574	2.734126	3.247202
G-OPTA-12	3.057575	2.937736	2.667959	2.6679589	2.780413	2.544428	2.701751	2.62309	2.828974	2.937736
G-OPTA-13	2.736042	3.141477	2.90446	2.9044599	4.337639	3.277862	3.98438	3.631121	2.691671	3.141477
G-OPTA-14	2.49381	2.718577	2.868376	2.8683756	2.924603	3.233641	3.027615	3.130628	2.521853	2.718577
G-OPTA-15	2.800931	2.696002	2.815981	2.8159814	2.6473	2.574247	2.622949	2.598598	3.001489	2.696002
G-OPTA-16	2.554368	2.824302	2.877397	2.8773967	3.277862	3.958201	3.504641	3.731421	2.564307	2.824302
G-OPTA-17	2.857158	4.304266	2.922502	2.922502	3.141477	2.824302	3.035752	2.930027	2.77658	3.352927
G-OPTA-18	2.7173	2.922502	4.137406	3.1860663	2.90446	2.877397	2.895439	2.886418	2.766641	2.922502

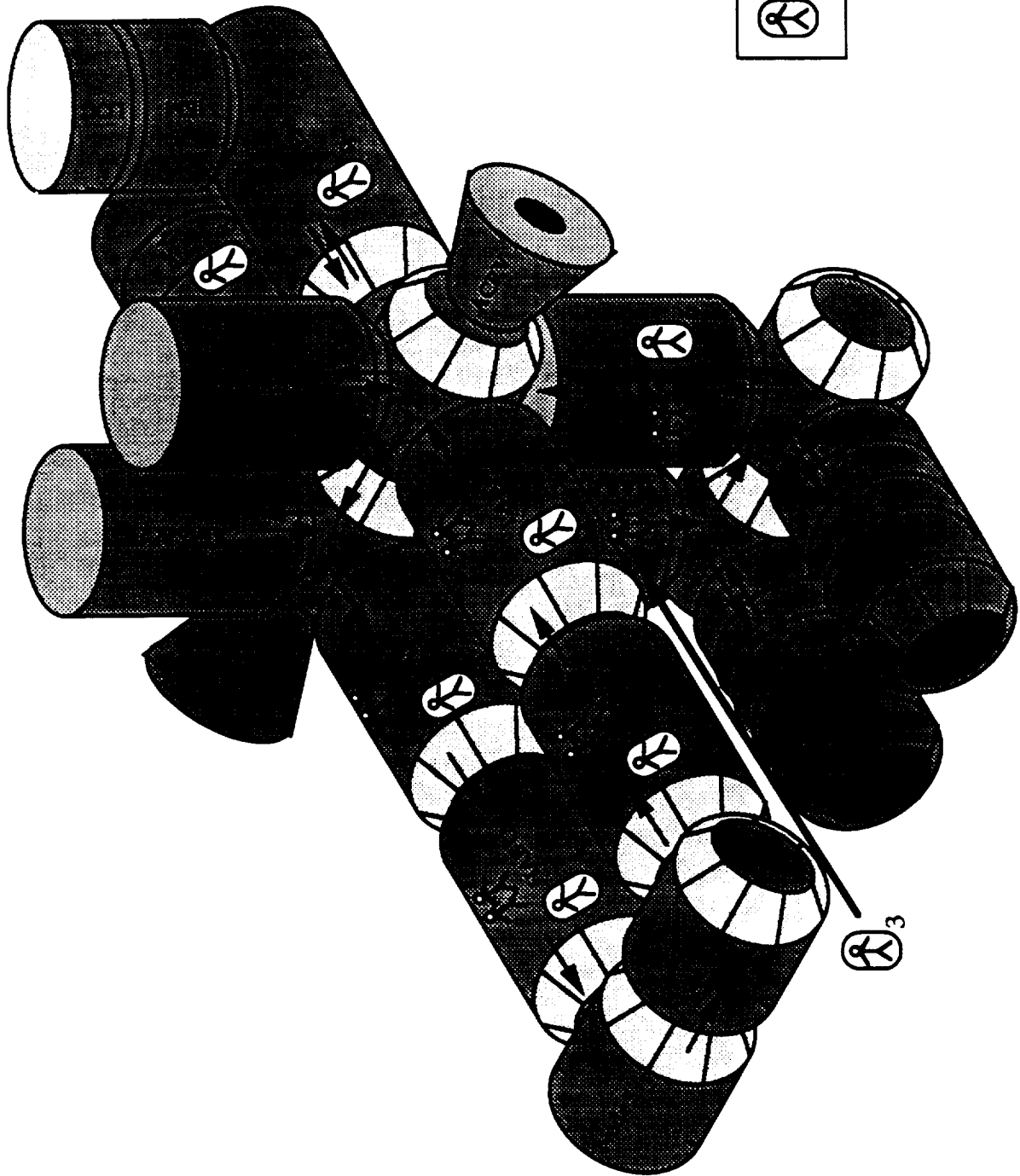
SSF Growth Option A Configuration Analysis of Trade Study Results



- With 12 crew and 3 ARs operating, the operational limit is only reached in a few cases (JEM, Airlock 1, and ESA). Parallel ventilation is generally better.

Growth Option A Configuration

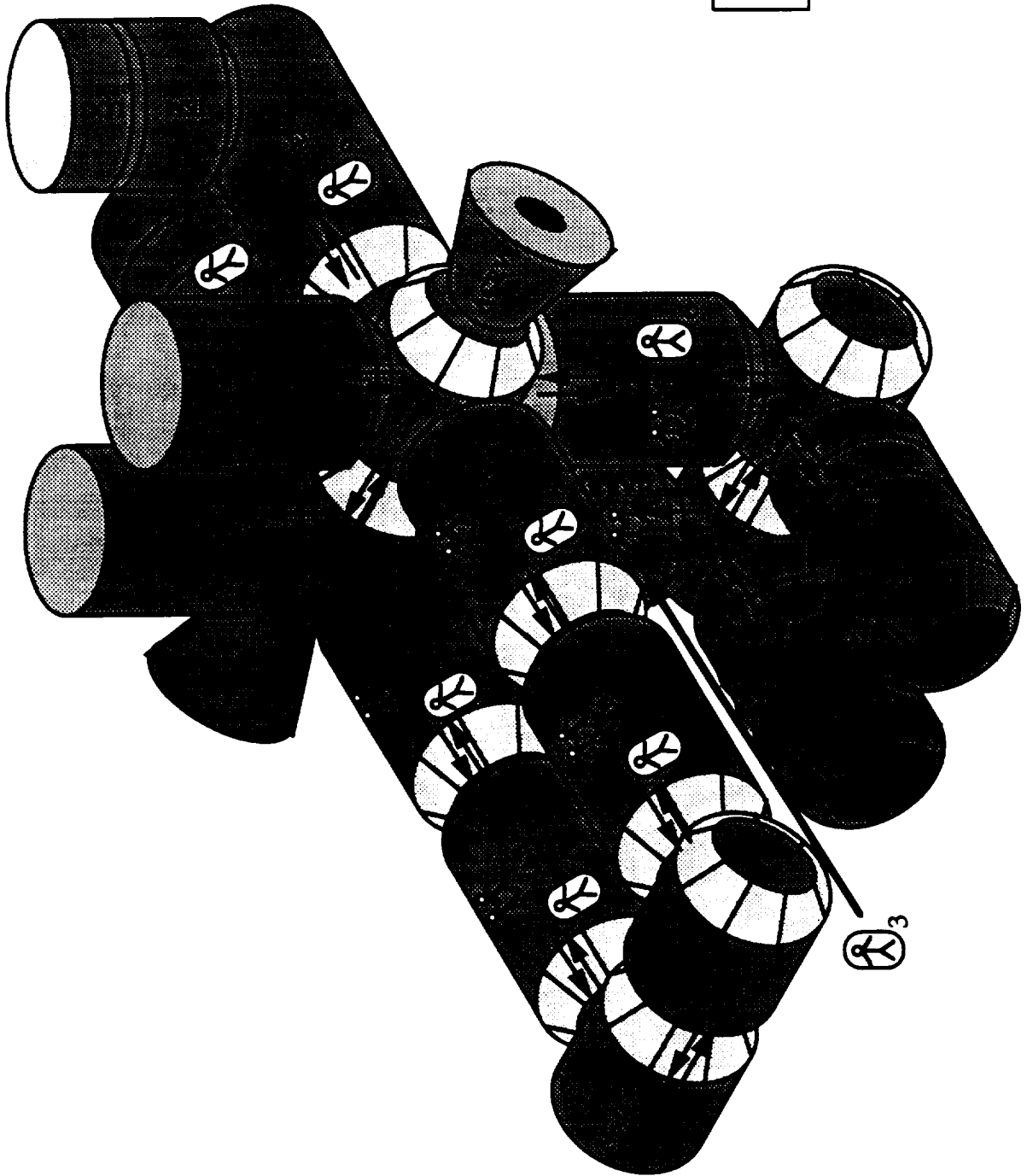
Racetrack




= 12 crew

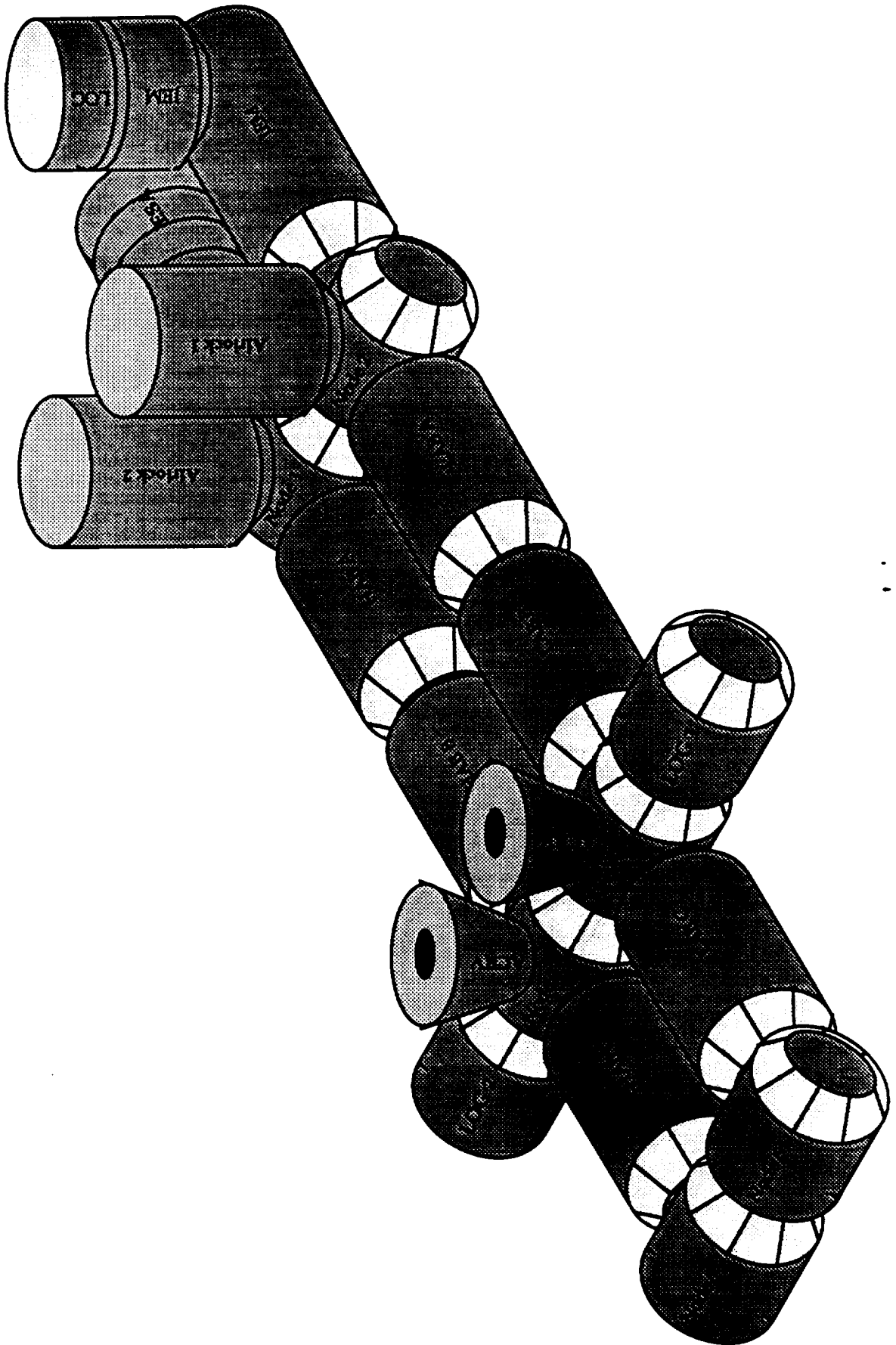
Growth Option A Configuration

Parallel



 = 12 Crew

Growth Option B Configuration



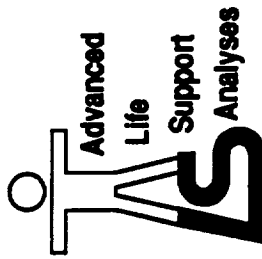
Growth Option B Configuration Trade Study Results

Case	Description	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4
G-OPTB-1	Racetrack, 12-Even, ARs in Hab B, Lab A, and Lab C	3.486	3.272	3.327	3.548	3.327	3.327	1.636	3.389
G-OPTB-2	Racetrack, 12-Hab A, ARs in Hab B, Lab A, and Lab C	4.044	3.630	3.092	3.445	3.092	3.092	1.815	3.445
G-OPTB-3	Racetrack, 12-Hab B, ARs in Hab B, Lab A, and Lab C	3.092	3.630	3.092	3.445	3.092	3.092	1.815	3.445
G-OPTB-4	Racetrack, 12-Hab C, ARs in Hab B, Lab A, and Lab C	3.259	2.926	3.259	3.630	3.259	3.259	1.463	3.630
G-OPTB-5	Racetrack, 12-Lab A, ARs in Hab B, Lab A, and Lab C	3.630	3.259	3.630	3.092	3.630	3.630	1.630	3.092
G-OPTB-6	Racetrack, 12-Lab B, ARs in Hab B, Lab A, and Lab C	3.630	3.259	3.630	4.044	3.630	3.630	1.630	3.092
G-OPTB-7	Racetrack, 12-Lab C, ARs in Hab B, Lab A, and Lab C	3.259	2.926	3.259	3.630	3.259	3.259	1.463	3.630
G-OPTB-8	Racetrack, 12-ESA, ARs in Hab B, Lab A, and Lab C	4.044	3.630	3.092	3.445	4.044	3.092	1.815	3.445
G-OPTB-9	Racetrack, 12-JEM, ARs in Hab B, Lab A, and Lab C	4.044	3.630	3.092	3.445	4.044	4.044	1.815	3.445
G-OPTB-10	Parallel, 12-Even, ARs in Hab B, Lab A, and Lab C	2.929	2.820	2.780	2.888	2.879	2.829	2.873	2.838
G-OPTB-11	Parallel, 12-Hab A, ARs in Hab B, Lab A, and Lab C	3.738	3.121	2.735	2.712	3.404	3.069	2.860	2.689
G-OPTB-12	Parallel, 12-Hab B, ARs in Hab B, Lab A, and Lab C	3.121	3.322	2.518	2.603	2.920	2.719	2.951	2.689
G-OPTB-13	Parallel, 12-Hab C, ARs in Hab B, Lab A, and Lab C	2.769	2.841	2.552	2.770	2.697	2.624	3.237	2.989
G-OPTB-14	Parallel, 12-Lab A, ARs in Hab B, Lab A, and Lab C	2.735	2.518	3.387	3.039	2.952	3.170	2.587	2.691
G-OPTB-15	Parallel, 12-Lab B, ARs in Hab B, Lab A, and Lab C	2.712	2.603	3.039	3.494	2.821	2.930	2.791	2.998
G-OPTB-16	Parallel, 12-Lab C, ARs in Hab B, Lab A, and Lab C	2.496	2.512	2.447	2.710	2.480	2.464	2.815	2.972
G-OPTB-17	Parallel, 12-ESA, ARs in Hab B, Lab A, and Lab C	5.900	5.432	5.400	5.531	6.367	5.884	5.583	5.662
G-OPTB-18	Parallel, 12-JEM, ARs in Hab B, Lab A, and Lab C	5.565	5.231	5.617	5.640	5.900	6.234	5.492	5.663

Growth Option B Configuration Trade Study Results (cont'd)

Case	Log 1	ESA	JEM	Airlock 1	Hab C	Lab C	Node 5	Node 6	Log 2	Airlock 2
G-OPTB-1	3.389	3.327	3.327	3.327	1.794	1.753	1.794	1.794	1.636	3.327
G-OPTB-2	3.445	3.092	3.092	3.092	1.815	1.630	1.815	1.815	1.815	3.092
G-OPTB-3	3.445	3.092	3.092	3.092	1.815	1.630	1.815	1.815	1.815	3.092
G-OPTB-4	3.630	3.259	3.259	3.259	2.414	2.167	2.414	2.414	1.463	3.259
G-OPTB-5	3.092	3.630	3.630	3.630	1.630	1.463	1.630	1.630	1.630	3.630
G-OPTB-6	3.092	3.630	3.630	3.630	1.630	1.463	1.630	1.630	1.630	3.630
G-OPTB-7	3.630	3.259	3.259	3.259	1.463	2.167	1.463	1.463	1.463	3.259
G-OPTB-8	3.445	4.995	3.092	3.092	1.815	1.630	1.815	1.815	1.815	4.044
G-OPTB-9	3.445	4.044	4.995	4.044	1.815	1.630	1.815	1.815	1.815	4.044
G-OPTB-10	2.838	2.879	2.829	2.829	2.962	2.753	2.892	2.823	2.873	2.879
G-OPTB-11	2.689	3.404	3.069	3.069	2.769	2.496	2.678	2.587	2.860	3.404
G-OPTB-12	2.689	2.920	2.719	2.719	2.841	2.512	2.731	2.622	2.951	2.920
G-OPTB-13	2.989	2.697	2.624	2.624	3.881	2.959	3.574	3.266	3.237	2.697
G-OPTB-14	2.691	2.952	3.170	3.170	2.552	2.447	2.517	2.482	2.587	2.952
G-OPTB-15	2.998	2.821	2.930	2.930	2.770	2.710	2.750	2.730	2.791	2.821
G-OPTB-16	2.972	2.480	2.464	2.464	2.959	3.393	3.104	3.248	2.815	2.480
G-OPTB-17	5.662	7.319	5.884	5.884	5.656	5.873	5.728	5.800	5.583	6.367
G-OPTB-18	5.663	5.900	7.186	6.234	5.583	5.856	5.674	5.765	5.492	5.900

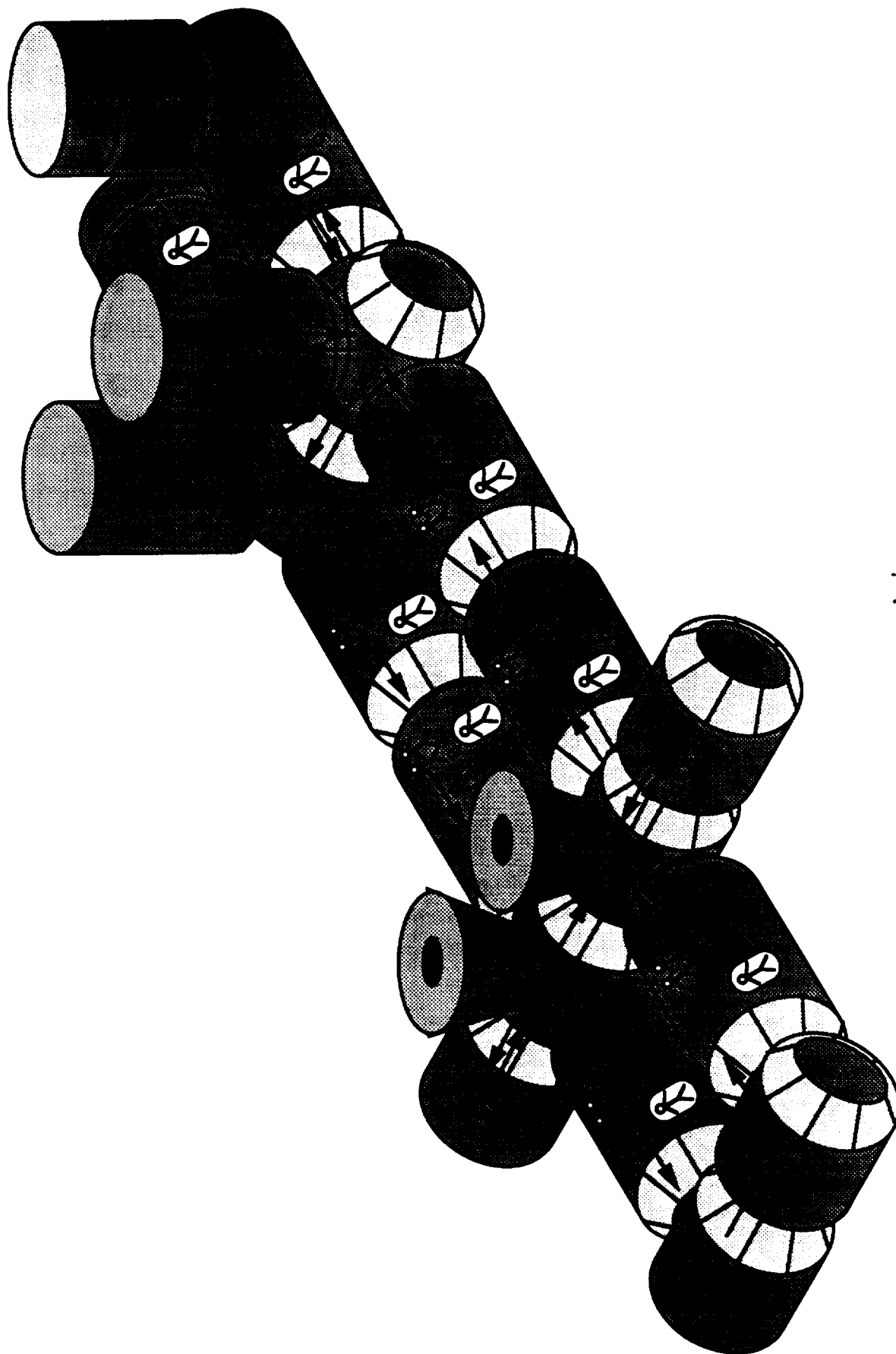
SSF Growth Option B Configuration Analysis of Trade Study Results



- With 12 crew and 3 ARs operating, the operational limit is exceeded in both parallel and racetrack ventilation paths.

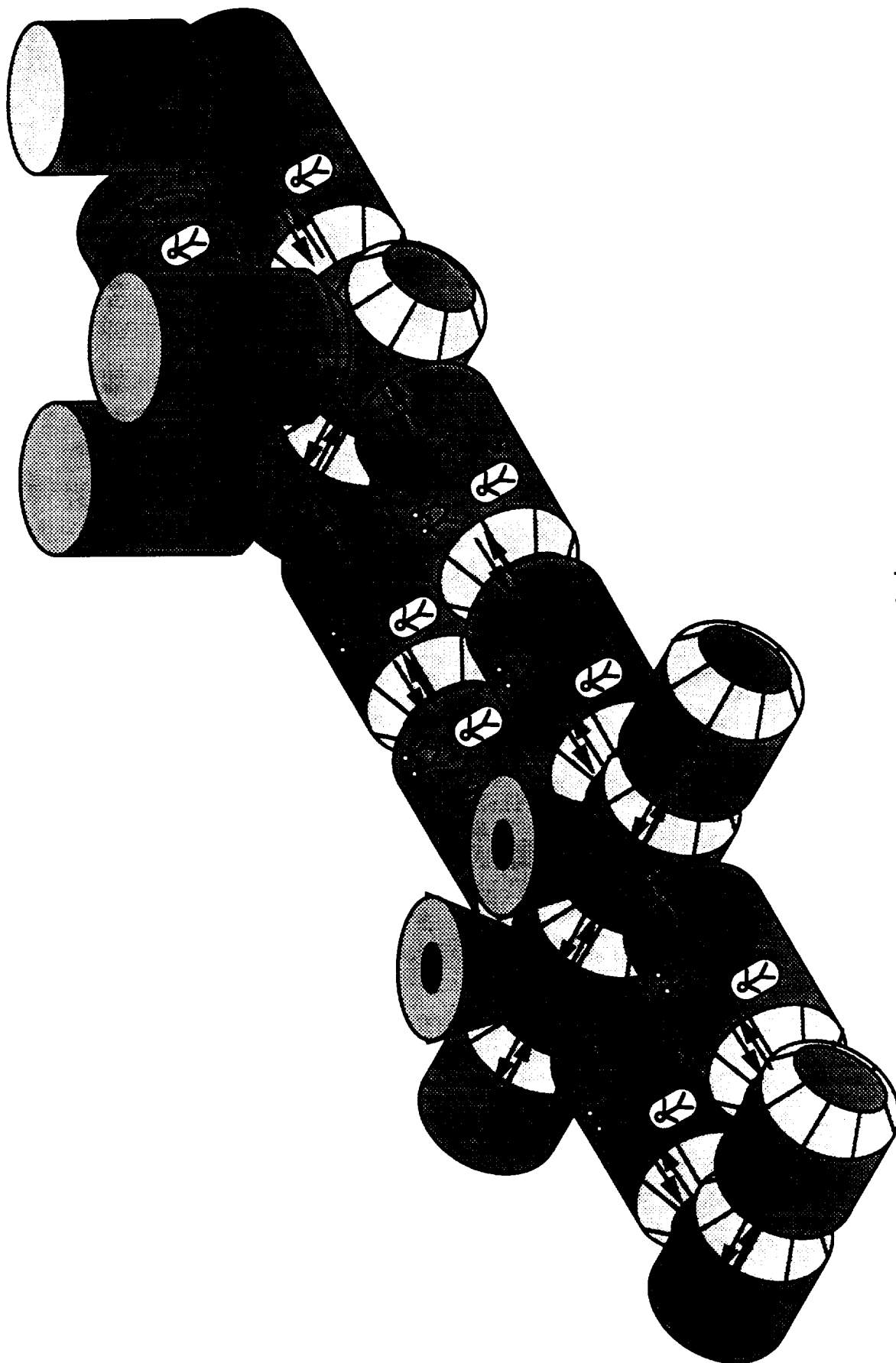
Growth Option B Configuration

Racetrack

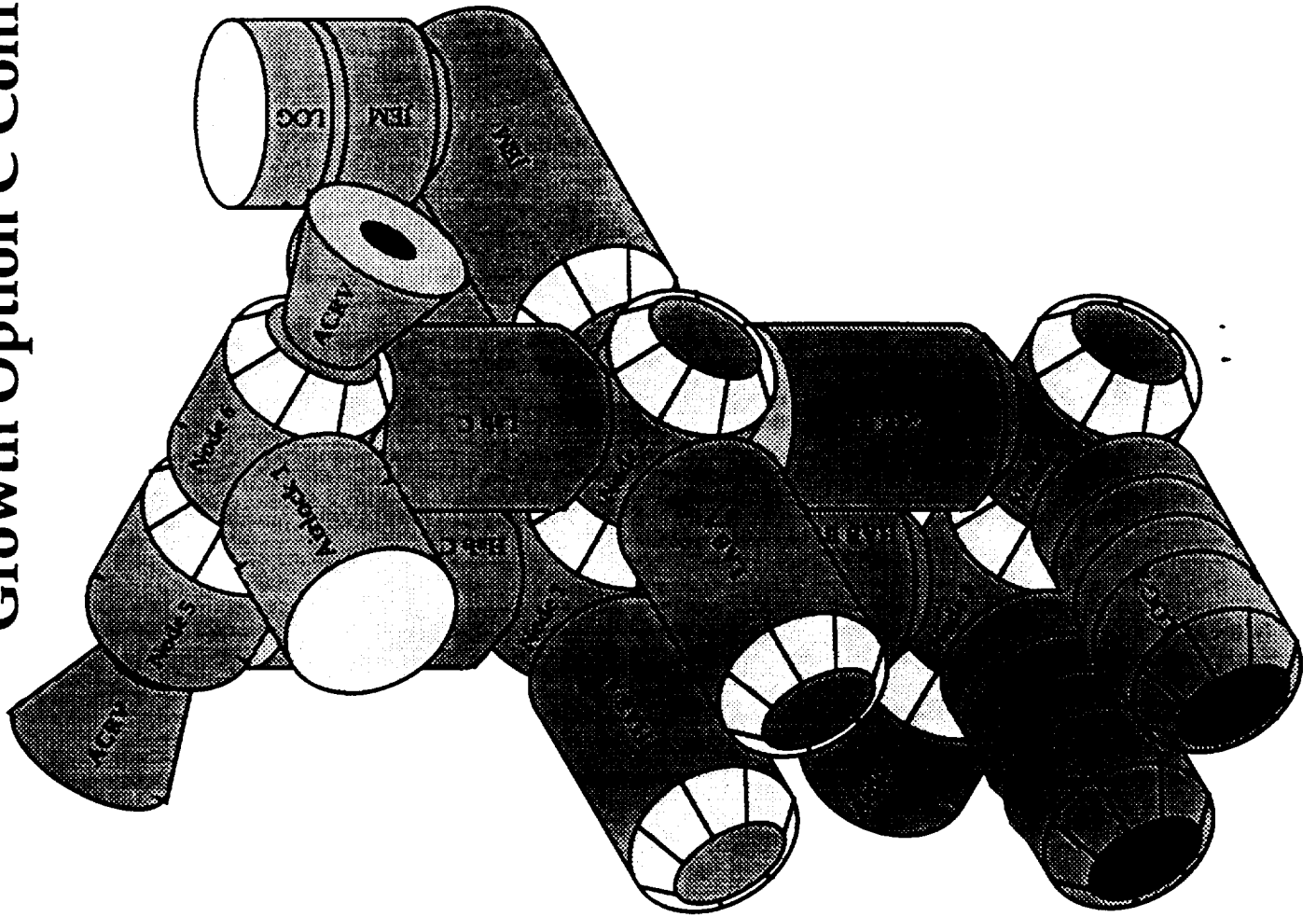


Growth Option B Configuration

Parallel



Growth Option C Configuration



Growth Option C Configuration Trade Study Summary

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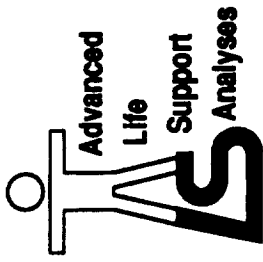
Growth Option C Configuration Trade Study Results

Case	Description	Hab A	Hab B	Lab A	Lab B	Node 1	Node 2	Node 3	Node 4
G-OPTC-1	Racetrack, 12-Even, ARs in Hab A, Lab B, and Lab C	2.689	2.996	5.980	2.832	2.837	5.822	2.996	2.996
G-OPTC-2	Racetrack, 12-Hab A, ARs in Hab A, Lab B, and Lab C	3.353	2.784	4.999	2.499	2.784	4.999	2.784	2.784
G-OPTC-3	Racetrack, 12-Hab B, ARs in Hab A, Lab B, and Lab C	3.749	5.127	8.779	4.603	4.176	8.779	5.127	5.127
G-OPTC-4	Racetrack, 12-Hab C, ARs in Hab A, Lab B, and Lab C	1.250	1.392	2.926	1.250	1.392	2.926	1.392	1.392
G-OPTC-5	Racetrack, 12-Lab A, ARs in Hab A, Lab B, and Lab C	2.784	3.101	7.471	2.784	3.101	6.520	3.101	3.101
G-OPTC-6	Racetrack, 12-Lab B, ARs in Hab A, Lab B, and Lab C	2.499	2.784	5.853	3.353	2.784	5.853	2.784	2.784
G-OPTC-7	Racetrack, 12-Lab C, ARs in Hab A, Lab B, and Lab C	2.499	2.784	5.853	2.499	2.784	5.853	2.784	2.784
G-OPTC-8	Racetrack, 12-ESA, ARs in Hab A, Lab B, and Lab C	5.284	5.885	11.421	5.284	5.885	11.421	5.885	5.885
G-OPTC-9	Racetrack, 12-JEM, ARs in Hab A, Lab B, and Lab C	5.284	5.885	12.372	5.284	5.885	12.372	5.885	5.885
G-OPTC-10	Parallel, 12-Even, ARs in Hab A, Lab B, and Lab C	2.845	3.099	3.146	2.888	3.011	2.987	3.028	2.958
G-OPTC-11	Parallel, 12-Hab A, ARs in Hab A, Lab B, and Lab C	3.624	2.964	2.770	2.597	3.086	2.770	2.841	2.719
G-OPTC-12	Parallel, 12-Hab B, ARs in Hab A, Lab B, and Lab C	3.652	4.701	3.853	3.745	4.068	3.853	4.382	4.064
G-OPTC-13	Parallel, 12-Hab C, ARs in Hab A, Lab B, and Lab C	2.462	2.643	2.513	2.345	2.743	2.513	2.544	2.445
G-OPTC-14	Parallel, 12-Lab A, ARs in Hab A, Lab B, and Lab C	2.605	2.897	4.158	2.883	2.901	3.206	2.892	2.887
G-OPTC-15	Parallel, 12-Lab B, ARs in Hab A, Lab B, and Lab C	2.921	3.390	3.418	3.800	3.254	3.418	3.527	3.663
G-OPTC-16	Parallel, 12-Lab C, ARs in Hab A, Lab B, and Lab C	1.807	1.999	2.164	1.956	2.013	2.164	1.984	1.970
G-OPTC-17	Parallel, 12-ESA, ARs in Hab A, Lab B, and Lab C	3.086	3.301	3.086	2.892	3.437	3.086	3.165	3.029
G-OPTC-18	Parallel, 12-JEM, ARs in Hab A, Lab B, and Lab C	2.605	2.897	3.206	2.883	2.901	3.206	2.892	2.887

Growth Option C Configuration Trade Study Results (cont'd)

Case	Log 1	ESA	JEM	Airlock 1	Hab C	Lab C	Node 5	Node 6	Log 2	Airlock 2
G-OPTC-1	2.996	2.837	5.822	2.996	2.996	2.832	2.996	2.996	2.996	2.996
G-OPTC-2	2.784	2.784	4.999	2.784	2.784	2.499	2.784	2.784	2.784	2.784
G-OPTC-3	5.127	4.176	8.779	5.127	4.176	4.176	4.176	4.652	5.127	5.127
G-OPTC-4	1.392	1.392	2.926	1.392	2.343	1.677	2.343	1.868	1.392	1.392
G-OPTC-5	3.101	3.101	6.520	3.101	3.101	2.784	3.101	3.101	3.101	3.101
G-OPTC-6	2.784	2.784	5.853	2.784	2.784	2.499	2.784	2.784	2.784	2.784
G-OPTC-7	2.784	2.784	5.853	2.784	2.784	3.353	2.784	2.784	2.784	2.784
G-OPTC-8	5.885	6.837	11.421	5.885	5.885	6.138	5.885	5.885	5.885	5.885
G-OPTC-9	5.885	5.885	13.324	5.885	5.885	6.138	5.885	5.885	5.885	5.885
G-OPTC-10	3.028	3.011	2.987	3.028	3.112	2.905	3.054	2.996	2.958	3.028
G-OPTC-11	2.841	3.086	2.770	2.841	2.986	2.628	2.885	2.785	2.719	2.841
G-OPTC-12	4.382	4.068	3.853	4.382	4.067	3.745	4.066	4.064	4.064	4.382
G-OPTC-13	2.544	2.743	2.513	2.544	3.352	2.451	3.010	2.669	2.445	2.544
G-OPTC-14	2.892	2.901	3.206	2.892	2.897	2.884	2.894	2.890	2.887	2.892
G-OPTC-15	3.527	3.254	3.418	3.527	3.285	3.201	3.317	3.348	3.663	3.527
G-OPTC-16	1.984	2.013	2.164	1.984	2.082	2.524	2.151	2.220	1.970	1.984
G-OPTC-17	3.165	4.389	3.086	3.165	3.326	2.927	3.214	3.102	3.029	3.165
G-OPTC-18	2.892	2.901	4.158	2.892	2.897	2.884	2.894	2.890	2.887	2.892

SSF Growth Option C Configuration Analysis of Trade Study Results




- With 12 crew and 3 ARs operating, the operational limit is exceeded in most cases and the degraded atmosphere limit is exceeded in several cases. Further study of the AR locations should be done.

Growth Option C Configuration

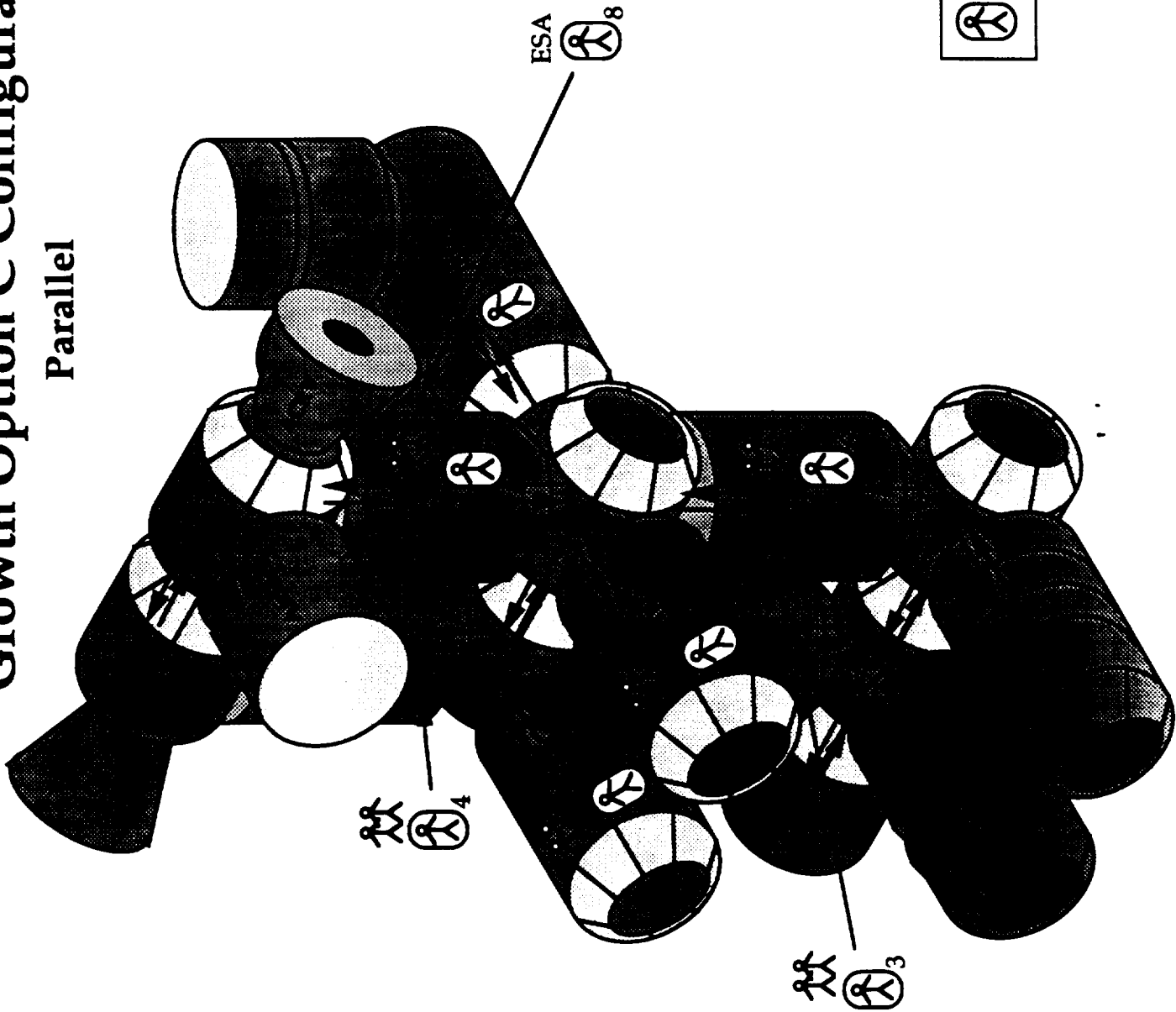
Racetrack



 = 12 Crew

Growth Option C Configuration

Parallel



- The concentration of CO₂ can be held below the operational limit either by one or a combination of the following methods:
 - 1) add additional operational ARs,
 - 2) reduce or avoid crew concentrations,
 - 3) improve the performance of the ARs
- Parallel ventilation paths generally provide lower CO₂ concentrations.
- The EMCC baseline configuration provides lower CO₂ concentrations than the EMCC Option C configuration.

Volume III - Appendix C
Task 3 Report
ECLSS Evolution: Advanced Instrumentation Interface Requirements

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

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Task 3 - ECLSS Evolution: Advanced Technologies Interface Requirements

The clarified statement of work for this task was understood as follows. Building on the Environmental Control and Life Support System (ECLSS) technologies database initiated by MacDonnell Douglas Space Systems Company (MDSSC), for each ECLSS technology, identify and describe the required interfaces including: fluid interfaces (flow rates, composition, temperature, pressure, etc.); electrical interfaces (average and minimum/maximum power levels, number of power lines, etc.); data/control interfaces (number of data/control lines, likely data rates, etc.; resupply (types of expendables including filters, reactors, etc. and the quantities).

An Advanced ECLSS Technology Interfaces Database was developed primarily to provide ECLSS analysts with a centralized and portable source of ECLSS Technologies interface requirements data. In addition to studying interface issues, this database provides data to the resupply analysis task and the "Hooks and Scars" study and Cost/Benefit analysis task. The database contains 20 technologies which were previously identified in the MDSSC ECLSS Technologies database. The primary interfaces of interest in this database are fluid, electrical, data/control interfaces, and resupply requirements. Each record contains fields describing the function and operation of the technology. Fields include: an interface diagram, a description, applicable design points and operating ranges, and an explanation of data, as required. A complete set of data was entered for six of the twenty components including Solid Amine Water Desorbed (SAWD), Thermoelectric Integrated Membrane Evaporation System (TIMES), Electrochemical Carbon Dioxide Concentrator (EDC), Solid Polymer Electrolysis (SPE), Static Feed Electrolysis (SFE), and BOSCH. Data for these 6 components has come from the ECLSS Technology Demonstrator Hardware (alias Technology Demonstration Program (TDP)) data books, primarily the Interface Control Documents (ICD). Additional data was collected for Reverse Osmosis Water Reclamation - Potable (ROWRP), Reverse Osmosis Water Reclamation - Hygiene (ROWRH), Static Feed Solid Polymer Electrolyte (SFSPE), Trace Contaminant Control System (TCCS), and Multifiltration Water Reclamation - Hygiene (MFWRH). A summary of database contents is presented in Exhibit C-1. Database printouts of the six completed data records are presented in Appendix E. With the database structure and report forms already developed, and pending the availability of data, the remaining data should be entered. The database is resident on the Macintosh computer with Foxbase+/Mac as the host software. Copies of the database have been delivered to NASA.

ECLSS Technologies Interface Data			Baseline ECLSS Technology	Interfaces Data Collected	Data in Interfaces Database
ECLSS Subsystem	Function	Technologies			
AR	CO ₂ Removal	4-Bed Molecular Mole Sieve (4BMS)	✓		
		2-Bed Molecular Mole Sieve (2BMS)			
		Lithium Hydroxide Canisters (LIOH)			
		Solid Amine Water Desorbed (SAWD)		✓	✓
		Electrochemical Depolarized CO ₂ Concentrator (EDC)		✓	✓
		Air Polarized CO ₂ Concentrator (APC or EDC W/WO H ₂)			
	CO ₂ Reduction	Bosch		✓	✓
		Sabatier	✓		
		Advanced Carbon Reactor (ACR)			
	O ₂ Generation	Static Feed Water Electrolysis (SFWE)	✓	✓	✓
		Solid Polymer Electrolysis - Liquid Anode Feed (SPE)		✓	✓
		Water Vapor Electrolysis (WVE)			
		Static Feed Solid Polymer Electrolyte (SFSPE)		✓	
	O ₂ Generation/CO ₂ Reduction	CO ₂ Electrolysis			
Airborne Contaminant Control	Trace Contaminant Control System (TCCS)		✓		
WRM	Urine Recovery	Thermoelectric Integrated Membrane Evaporation Subsystem (TIMES)		✓	✓
		Vapor Compression Distillation (VCD)	✓		
		Air Evaporation System (AES)			
	Water Processing	Vapor Phase Catalytic Ammonia Removal (VPCAR)			
		Reverse Osmosis (RO) *		✓	
		Multifiltration (MF) *	✓	✓	
		Electrodeioniation			

* Data has been collected for ROWR-Potable, ROWR- Hygiene, and MFWR-Hygiene

* Data has been collected for ROWR-Potable, ROWR-Hygiene, and MFWR-Hygiene

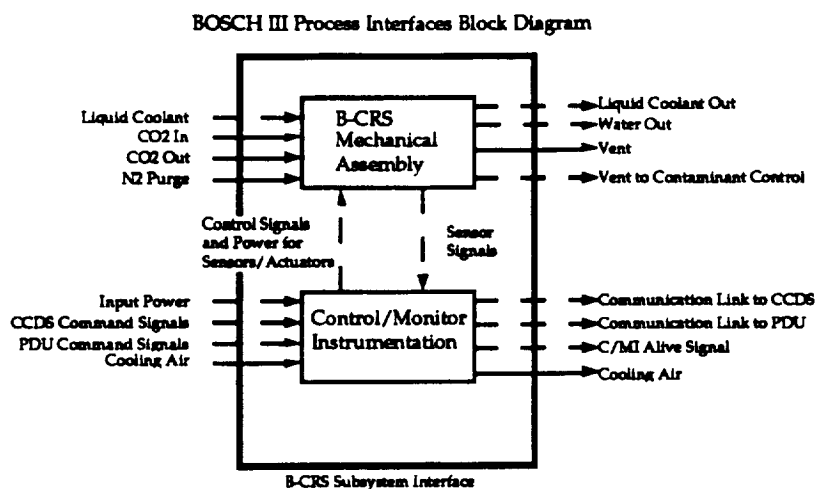
Exhibit C-1. Summary of Interface Database Contents

The gathering of technologies interfaces data was actively pursued but the applicable data is scarce. For the six entries in the interfaces database, we were able to locate lists of the ORU's but no real resupply data such as weights, rates, volumes, Mean Time to Repair (MTTR) and Mean time Between Failure (MTBF), was located.

Appendix C-1
Printout of the Interfaces Database

Advanced ECLSS Technologies Interfaces Database

Component name: BOSCH



<u>Type:</u>	<u>Description, units</u>	<u>Design Pt</u>	<u>Min</u>	<u>Max</u>	<u>Other</u>
Metabolic CO2					
	Flow Rate, lb/day	8.80	8.80	17.60	.
	Temperature, F	70.00	60.00	85.00	
	Pressure, psia	18.00	14.70	20.00	
H2 Feed					
	Flow Rate, lb/day	0.80	0.80	1.60	
	Temperature, F	75.00	75.00	100.00	

Advanced ECLSS Technologies Interfaces Database

Component name: BOSCH

Pressure, psia	30.00	14.70	30.00
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Product Water

Flow Rate, lb/day	7.20	7.20	14.40
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Temperature, F	60.00	60.00	90.00
----------------	-------	-------	-------

Pressure, psia	30.00	14.70	30.00
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Coolant (Water)

Flow Rate (lb/hr)	300.00	300.00	300.00
-------------------	--------	--------	--------

Temperature (In/Out), F — — — Design Point: In-42, Out-44; Range: In-42, Out-46

Pressure, psia	30.00	30.00	30.00
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Bleed (a)

Flow Rate, lb/day	1.12	1.12	1.12	(a) Applies to contaminated reactant feed gases
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Advanced ECLSS Technologies Interfaces Database

Component name: BOSCH

Temperature, F	75.00	65.00	90.00
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Pressure, psig	18.00	14.70	20.00
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Carbon Canister

Contents, lb	36.00	--	--
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Changeout Interval, days	15.00	7.50	15.00
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Electric Power

28 VDC, W	341.00	306.00	606.00
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115 AC, W	186.00	170.00	3120.00
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Heat Rejection, W

To Air	529.00	494.00	818.00
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To Coolant	238.00	181.00	461.00
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CCDS Communication Link

Advanced ECLSS Technologies Interfaces Database

Component name: BOSCH

CCDS Communication Link

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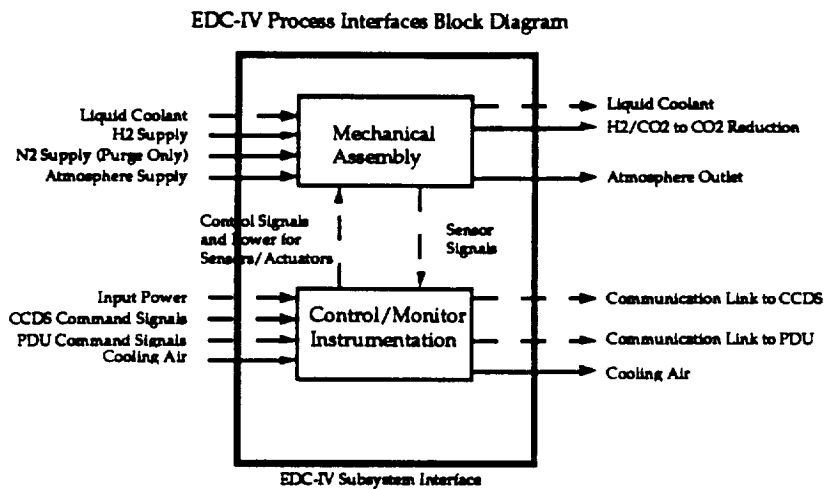
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— Design Point-
RS-232C

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Advanced ECLSS Technologies Interfaces Database

Component name: ELECTROCHEMICAL DEPOLARIZED CO2 CONCENTRATOR (EDC)



Type:	Description, units	Design Pt	Min	Max	Other
Conditioned Atmosphere					
	Rate, ACFM	54.00	—	—	.
	Temperature, F	70.00	60.00	85.00	
	Dew Point, F	50.00	35.00	70.00	
	Pressure, in H2O	—	—	—	
	pCO2, mmHG	2.70	—	12.00	

H2 Supply

Advanced ECLSS Technologies Interfaces Database

Component name: ELECTROCHEMICAL DEPOLARIZED CO2 CONCENTRATOR (EDC)

Rate, lb/day	1.39	—	1.89
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Pressure, psig	15.00	15.00	18.00
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Dew Point, F	50.00	40.00	65.00
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N2 Supply

Rate, slpm	6.00	—	—
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Pressure, psig	15.00	—	—
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Liquid Coolant

Fluid	—	—	—	Design Point- Water; Range- 50% Ethylene Glycol
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Rate, lb/hr	1600.00	1600.00	2500.00
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Temperature, F	40.00	40.00	46.00
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H2/CO2 Outlet

Advanced ECLSS Technologies Interfaces Database

Component name: ELECTROCHEMICAL DEPOLARIZED CO2 CONCENTRATOR (EDC)

Rate, lb/hr	9.90	—	18.90
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H2/CO2 Exhaust

Pressure, psig	3.00	—	5.00
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Electric Power

DC, W (28V)	192.00	—	—
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Total Heat Rejection

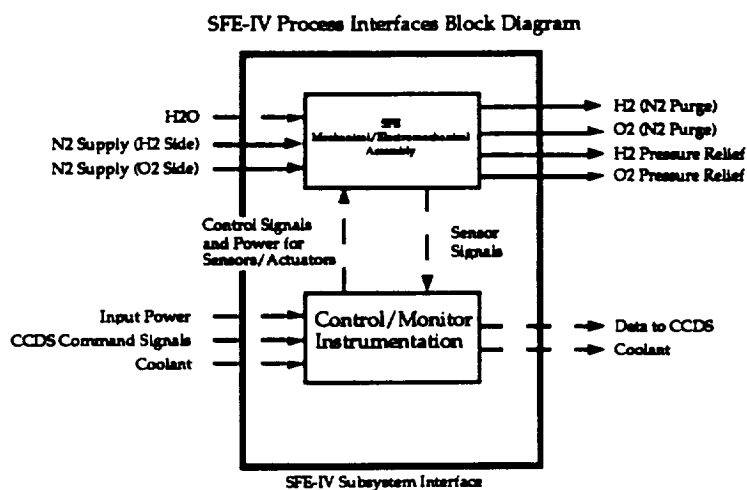
Total Heat Rejection	524.00	—	—	Range - <839
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CCDS Communication Link

CCDS Communication Link	—	—	—	Design Point - RS232
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Advanced ECLSS Technologies Interfaces Database

Component name: STATIC FEED WATER ELECTROLYSIS (SFWE)



Type:	Description, units	Design Pt	Min	Max	Other
Product O2					
	Pressure, psia	20.00	14.50	25.00	
	Temperature, F	70.00	60.00	85.00	
	Dew Point, F	54.00	40.00	65.00	
	Water Vapor, lb/day	0.09	—	0.12	
Product H2					
	Rate, lb/day	1.39	—	1.84	

Advanced ECLSS Technologies Interfaces Database

Component name: STATIC FEED WATER ELECTROLYSIS (SFWE)

Pressure, psia	20.00	14.50	25.00
----------------	-------	-------	-------

Temperature, F	70.00	60.00	85.00
----------------	-------	-------	-------

Dew Point, F	54.00	40.00	65.00
--------------	-------	-------	-------

Water Vapor, lb/day	0.18	—	0.23
---------------------	------	---	------

Water Feed

Rate, lb/day	12.78	—	16.92
--------------	-------	---	-------

Pressure, psia	30.00	30.00	35.00
----------------	-------	-------	-------

Temperature, F	70.00	60.00	85.00
----------------	-------	-------	-------

Quality	—	—	—	Design Point-Potable or Hygiene; Range-Potable or Hygiene
---------	---	---	---	---

N2 Supply (O2 Side)

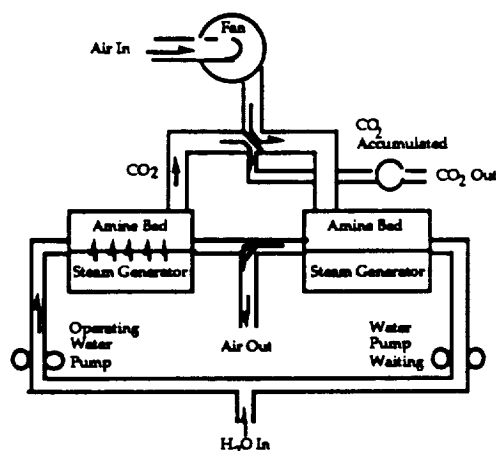
Advanced ECLSS Technologies Interfaces Database

Component name: STATIC FEED WATER ELECTROLYSIS (SFWE)

Rate, lb/day	0.08	—	1.00
Pressure, psia	182.00	180.00	185.00
N2 Supply (H2 Side)			
Rate, lb/day	—	—	1.00
Pressure, psia	182.00	180.00	185.00
Electric Power			
DC, W (28V)	96.00	—	96.00
DC, W (40V Nominal)	1162.00	—	1580.00
Total Heat Rejection, W			
Total Heat Rejection, W	216.00	—	220.00
CCDS Communication Link			
CCDS Communication Link	—	—	— Design Point-RS232, Range-RS232

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID AMINE WATER DESORBED (SAWD)



The Fundamental SAWD Process

Type:	Description, units	Design Pt	Min	Max	Other
Fluid - Inlet Process Air		---	---	---	.
	Flow Range, CFM	---	---	25.00	
	Pressure Range, IWG	---	---	-1.00	
	Temperature Range, deg F	---	40.00	50.00	
	Purity (in terms of the partial pressure of CO2 and the relative humidity)	---	---	---	CO2, 0-11 mm Hg, RH 90-100%

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID AMINE WATER DESORBED (SAWD)

Fitting/Line	--	--	--	Fitting: Size-2.0", Material-321SS, Type-V Band clamp style, MFGR-Aeroequip; Line: Size 2.0, Material-316SS
Fluid - Outlet Process Air				
Flow Range, CFM	--	--	25.00	
Pressure Range, IWG	--	--	1.00	
Temperature Range, deg F	--	--	--	55 - 110 deg F Maxium Average;165 deg F Maximum Instantaneous
Purity (in terms of the partial pressure of CO2 and the relative humidity)	--	--	--	CO2, 0-11 mm Hg, RH 90-100%
Fitting/Line	--	--	--	Fitting: Size-2.0", Material-321SS, Type-V Band clamp style, MFGR-Aeroequip; Line: Size 2.0, Material-316SS

Fluid - Hygiene H2O

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID AMINE WATER DESORBED (SAWD)

Flow Range, PPH	—	—	5.00
-----------------	---	---	------

Pressure Range, PSIG	—	—	10.00
----------------------	---	---	-------

Temperature Range, deg F	—	55.00	100.00
--------------------------	---	-------	--------

Purity	—	—	— Conductivity <10 micromhos/cm
--------	---	---	---------------------------------

Fitting/Line	—	—	— Fitting: Size-1/4", Material-321SS, Type-compression, MFGR-Crawford Fitting Co. (Swagelock); Line: Size 1/4", Material-316SS
--------------	---	---	---

Fluid - Vent

Flow Range, PPH	1.10	—	—
-----------------	------	---	---

Pressure Range, PSIA	—	—	— Ambient to 19.0
----------------------	---	---	-------------------

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID AMINE WATER DESORBED (SAWD)

Temperature Range, deg F	—	55.00	85.00	
Purity	—	—	—	1% Air, RH 100%
Fitting/Line	—	—	—	Fitting: Size-1/4", Material-321SS, Type-compression, MFGR-Crawford Fitting Co. (Swagelock); Line: Size 1/4", Material-316SS
Fluid - CO2 Outlet				
Flow Range, PPH	1.10	—	—	
Pressure Range, PSIA	—	—	—	Ambient to 19.0
Temperature Range, deg F	—	55.00	85.00	
Purity	—	—	—	1% Air, RH 100%

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID AMINE WATER DESORBED (SAWD)

Fitting/Line

—

—

— Fitting: Size-1/4",
Material-321SS,
Type-compression,
MFGR-Crawford
Fitting Co.
(Swagelock); Line:
Size 1/4",
Material-316SS

Instrumentation

—

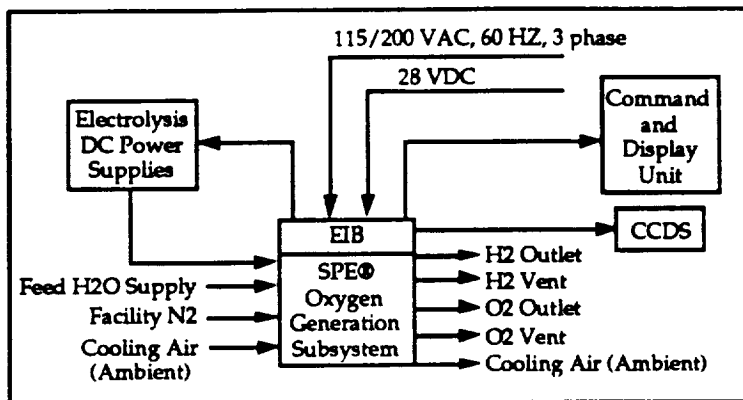
—

— There are no
external
instrumentation
interfaces for the
SAWD subsystem.
All data will be
provided via the
RS232C port.

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

SPE Oxygen Generation Subsystem Block Diagram



Type:	Description, units	Design Pt	Min	Max	Other
		—	—	—	.
Fluid - Feed H2O Supply					
Fitting/Line		—	—	—	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O2 Outlet					
Fitting/Line		—	—	—	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H2 Outlet					

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	---	---	---	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Facility N2				
Fitting/Line	---	---	---	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O2 Vent				
Fitting/Line	---	---	---	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H2 Vent				
Fitting/Line	---	---	---	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Cooling Air In				

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
--------------	---	---	---	---

Fluid - Cooling Air Out

Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
--------------	---	---	---	---

Fluid - Feed H2O Supply

Flow, LB/HR	0.52	0.01	0.69
-------------	------	------	------

Pressure, PSIA

35.00	25.00	45.00
-------	-------	-------

Temperature, deg F

—	60.00	120.00	The nominal or design point is Ambient Temperature.
---	-------	--------	--

Purity

—	—	—	Per MMC-ECLSS-2
---	---	---	-----------------

Fluid - O2 Outlet

Flow, LB/HR	0.46	0.01	0.61
-------------	------	------	------

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Pressure, PSIA	20.00	--	230.00	Minimum pressure is ambient
----------------	-------	----	--------	-----------------------------

Temperature, deg F	120.00	--	130.00	Minimum temperature is ambient.
--------------------	--------	----	--------	---------------------------------

Purity	--	--	--	>99.95% O2; see ICD for footnote
--------	----	----	----	----------------------------------

Fluid - H2 Outlet

Flow, LB/HR	0.06	--	0.08	
-------------	------	----	------	--

Pressure, PSIA	25.00	--	195.00	Minimum pressure is ambient
----------------	-------	----	--------	-----------------------------

Temperature, deg F	120.00	--	130.00	Minimum temperature is ambient.
--------------------	--------	----	--------	---------------------------------

Purity	--	--	--	>99.95% H2; see ICD for footnote
--------	----	----	----	----------------------------------

Fluid - Facility N2

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Flow, in ³ at start-up	67.00	67.00	67.00
-----------------------------------	-------	-------	-------

Pressure, PSIA	265.00	260.00	270.00
----------------	--------	--------	--------

Temperature, deg F	--	--	100.00	Minimum and nominal temperatures are ambient
--------------------	----	----	--------	--

Purity	--	--	--	High purity (99.99% N2)
--------	----	----	----	-------------------------

Fluid - O2 Vent

Flow, in ³ during ASD	8.50	8.50	8.50
----------------------------------	------	------	------

Pressure, PSIA	--	--	230.00	Minimum and Nominal Pressure is ambient
----------------	----	----	--------	---

Temperature, deg F	120.00	--	130.00	Minimum temperature is ambient
--------------------	--------	----	--------	--------------------------------

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Purity	—	—	—	see ICD for footnote
--------	---	---	---	----------------------

Fluid - H2 Vent

Flow, in ³ during ASD	73.00	73.00	73.00	
----------------------------------	-------	-------	-------	--

Pressure, PSIA	—	—	195.00	Minimum and Nominal Pressure is ambient
----------------	---	---	--------	---

Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient
--------------------	--------	---	--------	--------------------------------

Purity	—	—	—	see ICD for footnote
--------	---	---	---	----------------------

Fluid - Cooling Air In

Flow, CFM	85.00	85.00	85.00	
-----------	-------	-------	-------	--

Pressure, PSIA	—	—	—	All Pressures are ambient
----------------	---	---	---	---------------------------

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Temperature, deg F	—	—	—	Nominal temperature is ambient
--------------------	---	---	---	--------------------------------

Purity	—	—	—	Cabin Air
--------	---	---	---	-----------

Fluid - Cooling Air Out

Flow, CFM	85.00	85.00	85.00
-----------	-------	-------	-------

Pressure, PSIA	—	—	—	All Pressures are ambient
----------------	---	---	---	---------------------------

Temperature, deg F	—	—	—	Nominal temperature is ambient
--------------------	---	---	---	--------------------------------

Purity	—	—	—	Cabin Air
--------	---	---	---	-----------

Electrical - Instrumentation

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

-- -- -- There are no external instrumentation interfaces for the SPE Oxygen Generation Subsystem. All data will be provided via the RS232C port

Electrical - Cabling and Connectors

-- -- -- see ICD

Electrical - Data Bus Interface

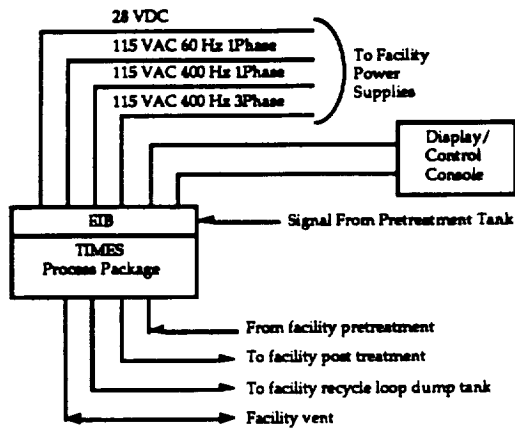
-- -- -- see ICD

Electrical - Facility Power

-- -- -- see ICD

Advanced ECLSS Technologies Interfaces Database

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION SUBSYSTEM (TIMES)



TIMES Block Diagram

Type:	Description, units	Design Pt	Min	Max	Other
Fluid - Inlet Waste Water					
	Flow Rate, LBM/HR	3.90	2.40	5.00	.
	Pressure, PSIA	20.00	15.00	25.00	
Fluid - Product Water					
	Flow Rate, LBM/HR	3.50	2.20	4.50	
	Pressure, PSIA	15.00	15.00	19.00	

Fluid - Inlet Waste Water

Advanced ECLSS Technologies Interfaces Database

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION
SUBSYSTEM (TIMES)

Fitting/Line	—	—	—	Fiting: Size-3/8", Material-Titanium, Type-Bulkhead Union -600-61, MFGR-SWAGLOK / Line: Size-3/8" Tube, Material-Titanium
--------------	---	---	---	--

Temperature, deg F	—	65.00	165.00	
--------------------	---	-------	--------	--

Fluid - Product Water

Fitting/Line	—	—	—	Fiting: Size-3/8", Material-Titanium, Type-Bulkhead Union -600-61, MFGR-SWAGLOK / Line: Size-3/8" Tube, Material-Titanium
--------------	---	---	---	--

Temperature, deg F	—	75.00	95.00	
--------------------	---	-------	-------	--

Fluid - Vent Gases

Flow Rate, LBM/HR	0.01	—	0.10	
-------------------	------	---	------	--

Pressure, PSIA	15.00	2.00	15.00	
----------------	-------	------	-------	--

Advanced ECLSS Technologies Interfaces Database

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION
SUBSYSTEM (TIMES)

Fitting/Line	—	—	—	Fitting: Size-1/4", Material-Titanium, Type-Bulkhead Union -600-61, MFGR-SWAGELOK TUBE / Line: Size-1/4", Material-Titanium
--------------	---	---	---	--

Temperature, deg F	—	75.00	90.00
--------------------	---	-------	-------

Fluid - Outlet Brine Water

Flow Rate, LBM/HR	550.00	500.00	600.00
-------------------	--------	--------	--------

Pressure, PSIA	20.00	15.00	25.00
----------------	-------	-------	-------

Fitting/Line	—	—	—	Fitting: Size-3/8", Material-Titanium, Type-Bulkhead Union -600-61, MFGR-SWAGELOK / Line: Size-3/8" Tube, Material-Titanium
--------------	---	---	---	--

Fluid - Cooling Air

Pressure, PSIA	—	—	—	Ambient
----------------	---	---	---	---------

Advanced ECLSS Technologies Interfaces Database

Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION
SUBSYSTEM (TIMES)

Temperature, Deg F 70.00 -- --

Fluid - Pressure Equilization Air

Flow Rate, CFM 1.30 1.30 1.30

Pressure, PSIA -- -- -- Ambient

Fitting/Line -- -- -- Fitting: Size-1/4",
Material-Titanium,
Type-Bulkhead
Union -600-61,
MFGR-SWAGELOK
/ Line: Size-1/4"
Tube,
Material-Titanium

Temperature, Deg F 70.00 -- --

Electrical - Instrumentation

Number: J308 Weight Sensor, Type: -- -- -- Pin 1, Signal +,
KJSE8N35SN, Mating Connector: 0-5VDC = 0-100LBS
KJ6F8N35PN, MFGR: ITT Cannon (+/- 0.02LBS); Pin 2,
Signal -; Pin 3, Case;
Pin 4, shield; Pin 5 &
Pin 6 Unused

Electrical - Cabling and Connectors

Advanced ECLSS Technologies Interfaces Database

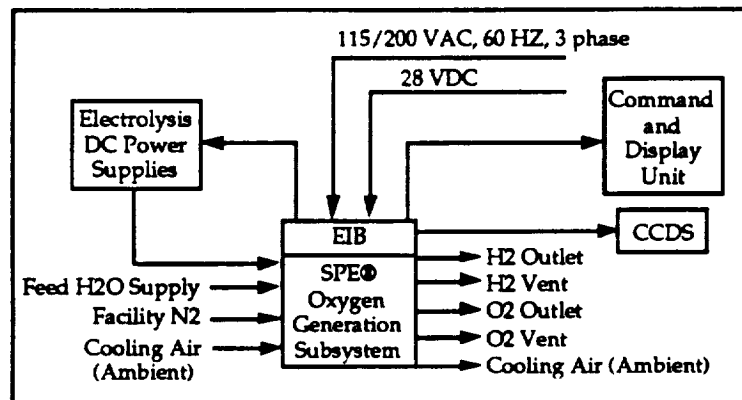
Component name: THERMOELECTRIC INTEGRATED MEMBRANE EVAPORATION
SUBSYSTEM (TIMES)

Number: J101 Primary 60 Hz Power, Type: KJ5E14N5PN,Mating Connector: KJ6F14N5SNN, MFGR: ITT Cannon	---	---	---	Pin A, 115 VAC, 60 Hz, Phase A; Pin B, 115 VAC, 60 Hz, Phase B, not used; Pin C; 115VAC, 60 Hz,Phase C, not used, Pin D, Neutral, Pin E, Safety Ground
Number: J102 Primary 400 Hz Power, Type: KJ5E14N5PA,Mating Connector: KJ6F14N5SA, MFGR: ITT Cannon	---	---	---	Pin A-115 VAC,400 Hz, Phase A; Pin B-115 VAC,400 Hz, Phase B, not used; Pin C-115VAC,400 Hz,Phase C, not used; Pin D-Neutral; Pin E-Safety Ground
Number: J201 CCDS Interface, Type: KJ53E10N35SN,Mating Connector: KJ6F10N35PN, MFGR: ITT Cannon	---	---	---	
Electrical - Data Bus Interface	---	---	---	There will be 8 data packets utilized by HSD hardware in Tech Demo.

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

SPE Oxygen Generation Subsystem Block Diagram



Type:	Description, units	Design Pt	Min	Max	Other
		---	---	---	.
Fluid - Feed H2O Supply					
	Fitting/Line	---	---	---	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O2 Outlet					
	Fitting/Line	---	---	---	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H2 Outlet					

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	--	--	--	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Facility N2				
Fitting/Line	--	--	--	Fitting: Size-1/4", Material-316SS, Type-Compression, MFGR-Swagelok, Line: Size-1/4", Material-316SS
Fluid - O2 Vent				.
Fitting/Line	--	--	--	Fitting: Size-1/2", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/4", Material-316SS
Fluid - H2 Vent				
Fitting/Line	--	--	--	Fitting: Size-1/4", Material-316SS, Type-O-ring, MFGR-Cajon, Line: Size-1/8", Material-316SS
Fluid - Cooling Air In				

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
Fluid - Cooling Air Out				
Fitting/Line	—	—	—	Fitting: Material-No, Type-Line, MFGR-Connections
Fluid - Feed H2O Supply				
Flow, LB/HR	0.52	0.01	0.69	.
				-
Pressure, PSIA	35.00	25.00	45.00	
Temperature, deg F	—	60.00	120.00	The nominal or design point is Ambient Temperature.
Purity	—	—	—	Per MMC-ECLSS-2
Fluid - O2 Outlet				
Flow, LB/HR	0.46	0.01	0.61	

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Pressure, PSIA	20.00	—	230.00	Minimum pressure is ambient
----------------	-------	---	--------	-----------------------------

Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient.
--------------------	--------	---	--------	---------------------------------

Purity	—	—	—	>99.95% O2; see ICD for footnote
--------	---	---	---	----------------------------------

Fluid - H2 Outlet

Flow, LB/HR	0.06	—	0.08	
-------------	------	---	------	--

Pressure, PSIA	25.00	—	195.00	Minimum pressure is ambient
----------------	-------	---	--------	-----------------------------

Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient.
--------------------	--------	---	--------	---------------------------------

Purity	—	—	—	>99.95% H2; see ICD for footnote
--------	---	---	---	----------------------------------

Fluid - Facility N2

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Flow, in ³ at start-up	67.00	67.00	67.00
-----------------------------------	-------	-------	-------

Pressure, PSIA	265.00	260.00	270.00
----------------	--------	--------	--------

Temperature, deg F	—	—	100.00	Minimum and nominal temperatures are ambient
--------------------	---	---	--------	--

Purity	—	—	—	High purity (99.99% N2)
--------	---	---	---	-------------------------

Fluid - O2 Vent

Flow, in ³ during ASD	8.50	8.50	8.50
----------------------------------	------	------	------

Pressure, PSIA	—	—	230.00	Minimum and Nominal Pressure is ambient
----------------	---	---	--------	---

Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient
--------------------	--------	---	--------	--------------------------------

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Purity	—	—	—	see ICD for footnote
--------	---	---	---	----------------------

Fluid - H2 Vent

Flow, in ³ during ASD	73.00	73.00	73.00	
----------------------------------	-------	-------	-------	--

Pressure, PSIA	—	—	195.00	Minimum and Nominal Pressure is ambient
----------------	---	---	--------	---

Temperature, deg F	120.00	—	130.00	Minimum temperature is ambient
--------------------	--------	---	--------	--------------------------------

Purity	—	—	—	see ICD for footnote
--------	---	---	---	----------------------

Fluid - Cooling Air In

Flow, CFM	85.00	85.00	85.00	
-----------	-------	-------	-------	--

Pressure, PSIA	—	—	—	All Pressures are ambient
----------------	---	---	---	---------------------------

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

Temperature, deg F	—	—	—	Nominal temperature is ambient
--------------------	---	---	---	--------------------------------

Purity	—	—	—	Cabin Air
--------	---	---	---	-----------

Fluid - Cooling Air Out

Flow, CFM	85.00	85.00	85.00
-----------	-------	-------	-------

Pressure, PSIA	—	—	—	All Pressures are ambient
----------------	---	---	---	---------------------------

Temperature, deg F	—	—	—	Nominal temperature is ambient
--------------------	---	---	---	--------------------------------

Purity	—	—	—	Cabin Air
--------	---	---	---	-----------

Electrical - Instrumentation

Advanced ECLSS Technologies Interfaces Database

Component name: SOLID POLYMER ELECTROLYSIS - LIQUID ANODE FEED (SPE)

-- -- -- There are no external instrumentation interfaces for the SPE Oxygen Generation Subsystem. All data will be provided via the RS232C port

Electrical - Cabling and Connectors

-- -- -- see ICD

Electrical - Data Bus Interface

-- -- -- see ICD

Electrical - Facility Power

-- -- -- see ICD

**Volume III - Appendix D
Task 4 Report
ECLSS Evolution: Resupply Analysis**

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

APPROVED BY: Jay H. Laue
Jay H. Laue
STG Vice President
Aerospace Systems

APPROVED BY: Dennis E. Homesley
Dennis E. Homesley
STG Vice President
Tactical Systems

SRS
TECHNOLOGIES

SYSTEMS TECHNOLOGY GROUP

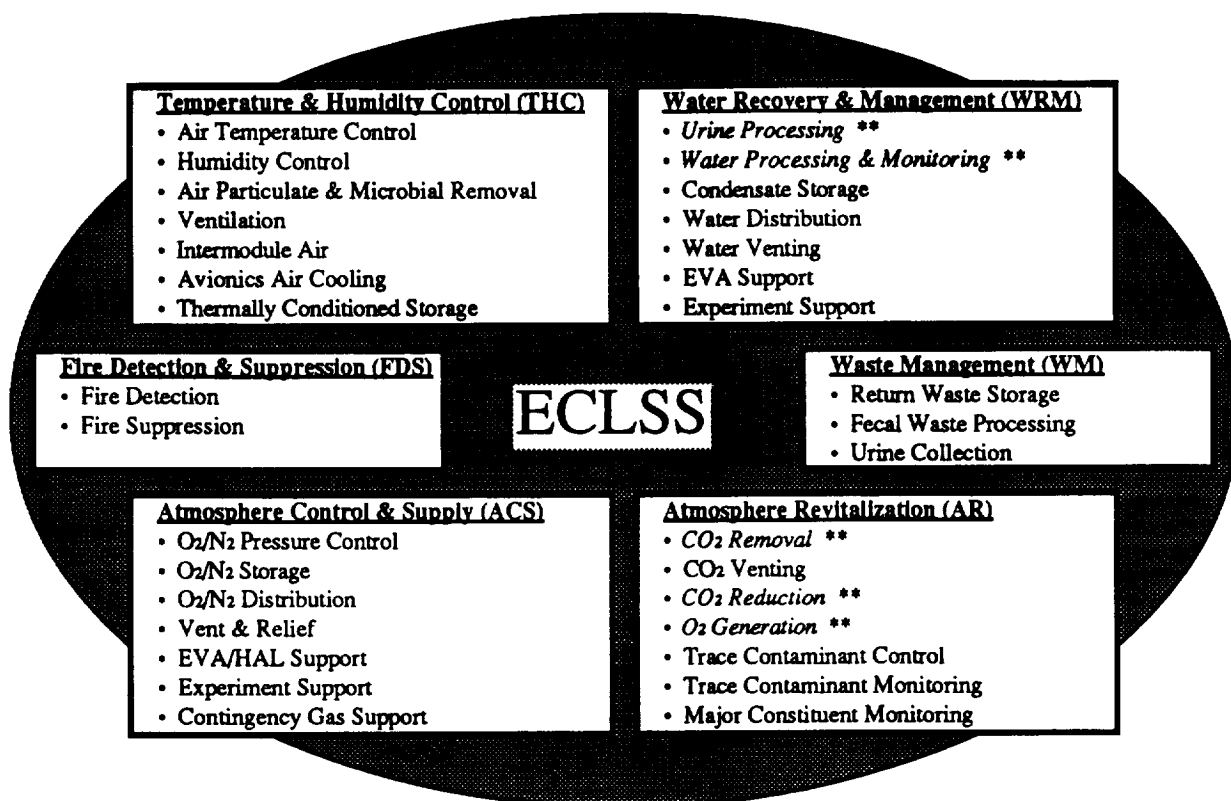
990 EXPLORER BLVD. N.W.
CUMMINGS RESEARCH PARK WEST
HUNTSVILLE, ALABAMA 35806
(205) 895-7000

Task 4 - ECLSS Evolution: Resupply Analysis

Based on the resupply requirements for each technology identified in Task 2 (the ECLSS Evolution: Intermodule Ventilation Study), this task called for the estimation of the logistics requirements to support each technology including analyses for different phases of Space Station *Freedom* evolution in which there will be different crew sizes, considering the potential for "economies of scale." Also, methods of reducing logistics weight and volume were to be recommended.

The purpose of this task was to determine the logistics requirements to support each ECLSS technology described in the Technology Database developed by McDonnell Douglas Space Systems Company (MDSSC) and to analyze the logistics requirements, for each technology, for different phases of the Space Station Freedom evolution in which there will be different crew sizes. Due to the lack of required data and inconsistency in the data gathered the effort focused on development of guidelines and procedures for a more meaningful technologies logistics requirements analysis. In addition, some issues to consider for reducing logistics weight and volume were also determined.

The ECLSS for the EMCC Space Station Freedom (SSF) configuration consist of six functional areas, each having multiple subsystems, as shown in Exhibit 2.5.2-1. The technologies described in the database are limited to Atmosphere Revitalization (AR) and Water Recovery and Management (WRM). The subsystems described in the database are CO₂ removal, CO₂ reduction, O₂ generation, urine processing, and water processing, as shown in Exhibit D-1. Exhibit D-2 is a list of the technologies included in the database. This exhibit shows the functions of each technology and their related ECLSS subsystem.



** Functional Areas Covered by the Technologies Database

Exhibit D-1. SSF ECLSS for the EMCC Configuration

ECLSS Subsystem	Function	Technologies
AR	CO ₂ Removal	4-Bed Molecular Mole Sieve (4BMS)
		2-Bed Molecular Mole Sieve (2BMS)
		Lithium Hydroxide Canisters (LHOH)
		Solid Amine Water Desorbed (SAWD)
		Electrochemical Depolarized CO ₂ Concentrator (EDC)
		Air Polarized CO ₂ Concentrator (APC or EDC W/WO H ₂)
	CO ₂ Reduction	Bosch
		Sabatier
		Advanced Carbon Reactor (ACR)
	O ₂ Generation	Static Feed Water Electrolysis (SFWE)
		Solid Polymer Electrolysis - Liquid Anode Feed (SPE)
		Water Vapor Electrolysis (WVE)
	O ₂ Generation/CO ₂ Reduction	CO ₂ Electrolysis
WRM	Urine Recovery	Thermoelectric Integrated Membrane Evaporation Subsystem (TIMES)
		Vapor Compression Distillation (VCD)
		Air Evaporation System (AES)
		Vapor Phase Catalytic Ammonia Removal (VPCAR)
	Water Processing	Reverse Osmosis (RO)
		Multifiltration (MF)
		Electrodeionization

Exhibit D-2. Technologies Included in the Technology Database

The related technologies can be better compared with each other by defining the logistics requirements, power penalty, heat rejection penalty, unit weight and volume, launch weight and volume, and operation life. Task 3 focused on defining the logistics requirements for each technology. However, due to a lack of detailed resupply information, the logistics requirements defined for the technologies are not sufficient to provide as meaningful analysis results as could be determined from a more comprehensive study. In order to develop meaningful logistics requirements and perform a more detailed logistics analysis and trade studies for each SSF evolution for each ECLSS technology, task 3 focused on the development of procedures for data collection, logistics analysis, and logistics trade studies, as described in the task flow shown in Exhibit D-3.

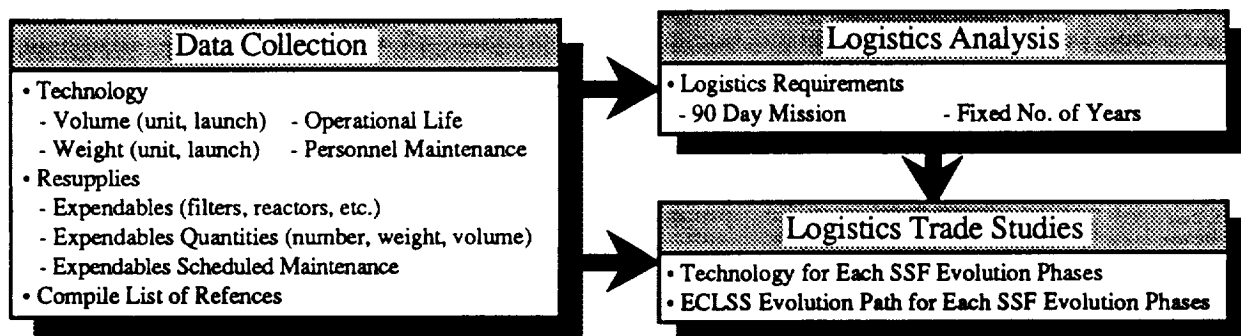


Exhibit D-3. Technologies Logistics Study Task Flow

Logistics requirements for each technology are based on resupply requirements and parameters that govern the transportation of the resupply items. The type of data to be collected can be broken down into categories, such as types of resupply expendables (filters, reactors, bottled gas, etc.), quantity of expendables, volume and weight (resupply, return, launch) of expendables, mean time between failures of expendables or operational life time, etc. In addition to these data categories, consideration should be given to the logistics involved with any special transportation environmental requirements (storage constraints - dimensions, temperature, power), special transportation packaging hardware, and personnel time required for maintenance. Exhibit D-4 shows a comparison of some of the higher level data collected for each of the technologies from two separate references. Due to inconsistencies in collected data, it was determined that 3 to 4 references should be used, if possible, to compare and verify the data collected. These inconsistencies can cause substantial error in the logistics analysis and trade studies. The information collected should then be summarized in a database to provide analysis capabilities in order to quickly perform logistics analysis and trade studies for the ECLSS technologies. Sources containing the required data for each technology should be compiled in a list for future reference and more detailed analysis.

ELCSS Technologies	Manrate (Person)		Weight (lb)						Volume (ft3)			
			Unit	90 Day				Unit	90 Day			
				Resupply		Return			Resupply	Return		
	Ref 1	Ref 2	Ref 1	Ref 2	Ref 1	Ref 2	Ref 1	Ref 2	Ref 1	Ref 2	Ref 2	Ref 2
4BMS	4	8	246	425	---	0		0	14.0	33.1	0	0
2BMS	4		180		---				13.0			
LiOH	4		10		1176				2.0			
SAWD	4		228		3				14.0			
EDC	4		169		---				5.0			
APC	4		190		---				6.0			
Bosch	4	8	725	689	377	205		637	32.4	39.1	21.8	21.8
Sabatier	4	8	114	114	264	0		0	2.4	2.4	0	0
ACR	4		600		24				23.0			
SFWE	4	8	160	160	---	---		---	3.6	---	---	---
SPE	4		230		---				6.0			
WVE	4		119		---				3.0			
CO2 Electrolysis	4		166		---				4.0			
TIMES	8	8	225	665	683	42		672	10.3	30.4	9.16	9.16
VCD	8		330		930				13.4			
AES	3		200		68				---			
VPCAR	8		300		800				18.0			
RO	8	8	566	1373	233	284		284	22.5	33.8	2.38	2.38
MF	8	8	160	1092	112	112		112	12.4	59.9	1.10	1.10
Electrodeionization	--		30		---				2.0			

Reference 1 - "Advanced ECLSS Subsystem and Instrumentation Technology Study for the Space Exploration Initiative", McDonnell Douglas Space Systems Co., Contract NAS8-36407, October 1990.

Reference 2 - Pre-Turbo SSF ECLSS Data received from Paul Wieland, NASA-MSFC, November 1990.

Exhibit D-4. Some ECLSS Technologies Logistics Related Characteristics

Once sufficient data is collected, logistics requirements for each technology can be determined. This can be accomplished by using the resupply requirements, maintenance requirements, component operational life and operational capabilities data to calculate the logistics requirements for a given crew size and resupply period. By accounting for a technology's unit weight and volume, its operational life, and the major components' operational life, the technology's logistics requirements can be analyzed based on a set number of years. This would allow the related technologies to be compared based on total logistics requirements of transportation and maintenance for an extended length of time, such as the planned operational life time of the SSF. The technologies logistics data should then be summarized with a listing of any special transportation requirements that would require additional logistics.

From the information collected and the logistics requirements defined, various trade studies could be performed for better characterization and comparison of the related ECLSS technologies. These trade studies should include a study to determine the logistics requirements of the technologies based on each proposed SSF evolution configuration in which there will be different crew sizes. This study should involve defining the logistics requirements per 90-day resupply mission and total logistics requirements for a set number of years. Special consideration should be

given to "economies of scale," such as reduction of total resupply logistics requirements per technology given an increase in the number of crews.

With the information developed from the resupply and logistics requirements study, an evaluation of the total logistics requirements for each SSF evolutionary configuration path could be conducted. An example task flow for this type of study is shown in Exhibit D-5. This study might include determining proposed ECLSS evolutionary paths (technology combinations and proposed technology upgrade or replacement) for each SSF evolutionary configuration path. The study should not include combinations of functionally related technologies, such as Bosch or Sabatier for CO₂ reduction, due to lack of commonality and increased logistics requirements. These trade studies would provide meaningful results that can be better used for determining the ECLSS configurations and evolution paths that minimize total ECLSS logistics requirements.

In order to reduce the logistics requirements for each technology (unit volume and weight, resupply requirements, etc.), consideration might be given to some of the issues shown in Exhibit D-6. The first two issues could be addressed through ventilation trade studies similar to the studies performed in task 1 of this contract. The later two issues would require detailed knowledge of the design, operations, and performance of each technology. Therefore, the later two issues might be better addressed by the developer of each ECLSS technology.

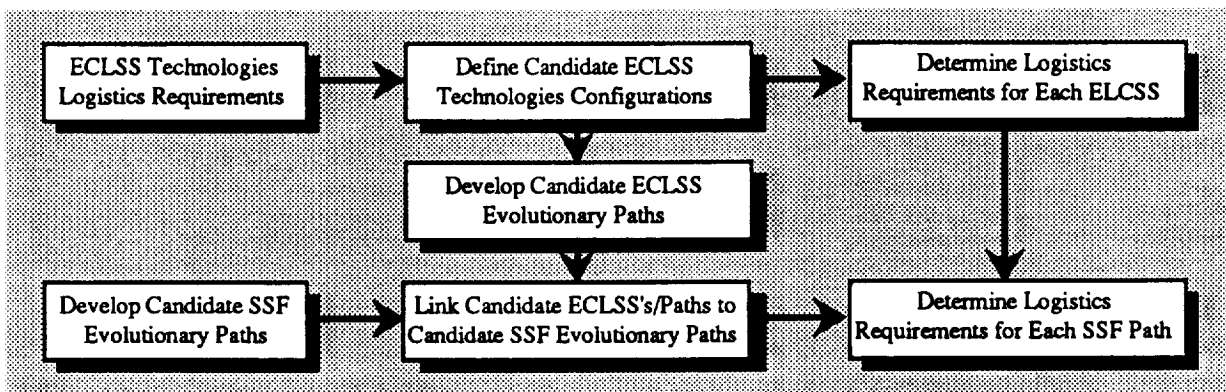


Exhibit D-5. Logistics Trade Study Task Flow for ECLSS Evolutionary Paths

1. Can the number of AR's required be reduced through improved ventilation and selection of optimum locations?
2. Should limitations be placed on the personnel concentration per area?
3. Can design modifications be made to improve performance?
 - Extended components operational life
 - Reduced weight and volume per unit or components
 - Increase man-rate limit to reduce the number of required units and resupplies
4. Can operations be simplified to reduce maintenance and resupply requirement?

Exhibit D-6. Logistics Requirement Reduction Issues

Results

The primary work accomplished under this task was a cursory evaluation of the ways to reduce logistics weight and volume. One recommendation from the cursory evaluation is to place the THCS for the logistics module in the node it attaches to. This would eliminate the need to repeatedly launch and return the THCS and would therefore allow more resupply mass and volume to be carried on the logistics module. A complete report is presented in Appendix D.

**Volume III - Appendix E
Task 5 Report
ECLSS Evolution: Module Addition/Relocation**

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

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Task 5 - ECLSS Evolution: Module Addition Relocation

The purpose of this task was to evaluate aspects other than ventilation as modules are added or relocated and as interior rearrangements are made. This task is an extension of the intermodule ventilation trade studies. Furthermore, this task involved development of ECLSS growth concepts consistent with SSF's growth phases and identified impacts such as additional interconnections required and other effects.

The following assessment identified studies recommended to insure that critical resources and ECLSS functional requirements are maintained during station configuration changes and evolutionary growth, including module addition and relocation, and that safe haven requirements are also met for each evolving configuration and during configuration changes. Examples of growth configurations that require analysis are described in Task 1 SSF Evolution Concepts Ventilation Trade Studies. Crew safety requirements are contained in SSP 30000 Section 3 Revision K. The following quote is from SSP 3000 Section 3 Revision K: "In general, station systems functions which are essential for crew safety and station survival shall be two failure tolerant as a minimum (except for primary structure and pressure vessels in the rupture mode). During initial station assembly and periods of maintenance these systems functions shall be single failure tolerant as a minimum and on-orbit restorable. Table 3-2.2 from SSP 30000 Section 3 Revision K, provides functional failure tolerance requirements. The space station shall provide the capability to isolate any element containing a catastrophically hazardous event from the remainder of the Space Station. In the event of any single failure, including the complete loss of one pressurized element, the space station shall provide safe haven capabilities to insure crew survival for a maximum duration of 22 days." Exhibit E-1 contains table 3.2-2 from SSP 30000 Section 3, revision K.

TABLE 3-2.2 SSMB FUNCTIONAL FAILURE TOLERANCE REQUIREMENTS

FUNCTION	PRIME SUPPORTING SYSTEM ⁴	CATEGORY	REQUIRED FAILURE TOLERANCE ^{1,2,3,5}	
			MTC	PMC
1.0 Provide Safe & Healthy Working Environment				
1.1 Respirable Atmosphere				
1.1.1 O ₂ Generation/O ₂ Supply	ECLSS	1C	N/A	2
1.1.2 O ₂ /N ₂ Storage	ECLSS	1C	1	2
1.1.3 O ₂ /N ₂ Distribution	ECLSS	1C	1	2
1.1.4 O ₂ /N ₂ Pressure Control	ECLSS	1C	1	2
1.1.5 CO ₂ Venting (PMC)/Reduction (AC)	ECLSS	1C	0	2
1.1.6 CO ₂ Removal	ECLSS	1C	0	2
1.1.7 Air Particulate & Microbial Control	ECLSS	1C	1	2
1.1.8 Cabin Air Temperature and Humidity Control	ECLSS	1C	1	2
1.1.9 Circulation	ECLSS	1C	1	2
1.1.10 Vent & Relief	ECLSS	1C	1	2
1.1.11 Atmosphere Composition Monitoring	ECLSS	1C	0	2
1.1.12 Trace Contaminant Monitor	ECLSS	1C	N/A	2
1.1.13 Trace Contaminant Control	ECLSS	1C	0	2
1.2 Operational Lighting				
1.2.1 General Lighting	Element Unique	2	1	1
1.2.2 Task Lighting	Element Unique	3	0	0
1.3 Acoustics				
1.3.1 Hearing Conservation Acoustic Control	Element Unique	3	0	0
1.3.2 Severe Discomfort Vibration Control	Element Unique	3	0	0
1.4 Food				
1.4.1 Food Storage	MS	1C	N/A	2
1.4.2 Food Preparation	MS	2	N/A	1
1.4.3 Food Waste Collection/Storage	MS	2	N/A	1
1.5 Wear (Possible/Hygiene)				
1.5.1 Wear Storage	ECLSS	1C	N/A	2
1.5.2 Wear Processing	ECLSS	1C	N/A	2
1.5.3 Wear Thermal Conditioning	MS	3	N/A	0
1.5.4 Wear Distribution	ECLSS	2	N/A	1
1.6 Personal Hygiene				
1.6.1 Reserved				
1.6.2 Full Body Cleansing	MS	3	N/A	0
1.6.3 Handwash/Partial Body Cleansing	MS	2	N/A	1
1.6.4 Urine Collection	ECLSS	1C	N/A	2
1.6.5 Urine Processing	ECLSS	2	N/A	1
1.6.6 Urine Storage	ECLSS	1C	N/A	2
1.6.7 Urine Removal	ECLSS	2	N/A	1
1.6.8 Fecal Waste Collection	ECLSS	1C	N/A	2

¹When present prior to PMC, the Space Shuttle may be considered as an additional path of redundancy to this table.

²Requirements apply from the primary stage listed up to, but not including, the next primary stage.

³In circumstances where a conflict exists between required failure tolerances, the most stringent requirement takes precedence.

⁴This column is intended to add clarity to the function descriptions. It is not a requirement nor a part of the functional partitioning.

⁵Failure tolerances for specific applications is achieved by superposition of these functional failure tolerance requirements with the safety failure tolerance requirements.

⁶These functions shall be one failure tolerant at PMC minus one assembly flight.

⁷For PMC and following, crew survival functions may achieve two failure tolerances by using the ACSF in lieu of a redundant path.

⁸These Category 1 functions that are shown to be time critical may be required to be 2 failure tolerant.

Exhibit E-1. Table 3-2.2 from SSP 30000 Section 3 Revision K

ECLSS functions recommended for assessment to meet redundancy and safe haven requirements for each evolving configuration including module addition and/or relocation (excluding intermodule ventilation) are as follows:

- O₂/N₂ storage and distribution
- Cabin air temperature and humidity control (including avionics air cooling)
- Trace contaminant control
- Water storage and processing and distribution
- Urine processing storage
- Fecal waste collection
- Food storage

A study approach overview applicable to each of the above ECLSS functions is shown in Exhibit E-2. In each case the ECLSS requirements from the applicable documents should be used to develop study groundrules and requirements. Once the requirements are understood and a specific configuration has been selected the assessments can be made by developing a subsystem model and applying the model to the specific configurations or constraints of interest. The results including issues and recommendations can be reported and documented as indicated in the Exhibit E-3.

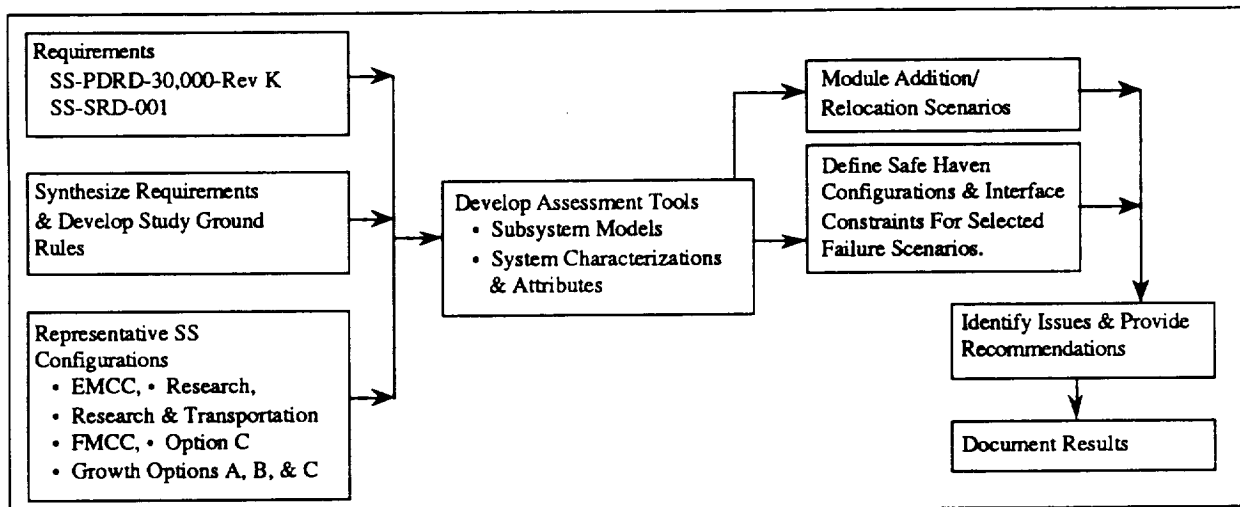


Exhibit E-2. Study Approach Overview

ECLSS Function	Recommended Study
O ₂ /N ₂ Distribution	<ul style="list-style-type: none"> • Evaluate Space Station Build Up Scenarios • Evaluate Capability For Safe Haven Rqmts And Skipped Resupply • Identify Best Distribution Of Stored O₂/N₂ To Minimize Impacts Of Catastrophic System Loss
Cabin Air Temperature and Humidity Control	<ul style="list-style-type: none"> • Evaluate Function Distribution To Assure Safe Haven Reqmts Are Satisfied • Evaluate System Performance & Function Distribution To Assure That Space Station Growth Configurations & Build Up Scenario Requirements Can Be Satisfied • Evaluate System To Investigate Feasibility Of Removing Temperature & Humidity Control Equipment From Logistics Modules
Trace Contaminant Control	<ul style="list-style-type: none"> • Evaluate Trace Containment Control & Monitoring Capability For Configurations Build Up & Failure Scenarios Requiring A Safe Haven - Identify Distributions Of Monitoring And Control Equipment That Support Build Up And Safe Haven Requirements.
Water Storage, Processing, and Distribution	<ul style="list-style-type: none"> • Determine Adequacy Of Water Distribution System To Provide Redundant Paths To Accommodate Failure, Or Removal Of A Pressurized Module • Determine Capability To Accommodate Loss Of Processing Capability And Water Due To Loss Or Removal Of A Pressurized Modules
Fecal Waste Collection	<ul style="list-style-type: none"> • Assess Adequate Distribution Of Fecal Waste Collection Systems To Assume Safe Haven Requirements Can Be Met
Food Storage	<ul style="list-style-type: none"> • Assess Food & Equipment Distributions For Each Growth Configuration To Assure That Safe Haven Requirements Can Be Satisfied
System Study	<ul style="list-style-type: none"> • Combine The Results Of The Previous Studies And Other Information As Required To Define A Safe Haven Configuration For Each Growth Configuration And Failure Scenario

Exhibit E-3. Summary of Recommended Studies

O₂/N₂ Storage and Distribution

The PDRD 30000 Rev. K requires a Safe Haven for 22 days. A skip cycle or missed resupply requires 90 days of atmosphere gas. This includes 45 days of normal operation plus 45 days "safe mode" plus three, two person EVAs plus one hyperbaric treatment. A CR to revision K increases the crew survival requirements to 45 days, and provides for a delayed resupply of 90 days.

Based on atmosphere gas allocations (user requirements), resupply capabilities (cryo tankage storage capabilities and residuals, etc.), and the above requirements the capability of the system to meet the requirements can be assessed. From a brief review of the PDRD requirements there appears to be no requirements for distributing the stored gas such that a catastrophic event causing the loss of one storage system could be accommodated. In other words there is no backup

gas storage system onboard the station. As the space station grows in crew and elements, a study objective could be to evaluate the benefits of distributing the gas storage to minimize the effects of losing one set of storage tanks, and to insure that safe haven and skip cycle requirements can be met for all growth configurations.

Cabin Air Temperature and Humidity Control

The temperature and humidity control system must be capable of meeting the safe haven requirements, and also have the flexibility to accommodate module additions and relocations.

These top level requirements and space station growth configuration characteristics will allow definition of thermal loads (crew and equipment and structural heat leak). A TRASYS/SINDA thermal model may be needed to evaluate the structural heat transfer, for the evolving configurations. A coolant loop model including the sensible and latent heat removal characteristics of the heat exchangers can be formulated to predict atmosphere temperatures and humidities for various build up scenarios and failure conditions.

These models can be used to assess the thermal control system capabilities for various configurations, failures, and build up scenarios. Study objectives would be to assess the configurations' build up scenario to determine that the thermal control system can meet temperature and humidity requirements; assess various failure scenarios and determine the optimum "safe haven" configuration for each failure case, and finally to evaluate for each configuration the need to provide heat exchanges in logistics modules. Fixed equipment weight and volume in the logistics modules is very expensive because it is launched repeatedly.

Trace Contaminant Control

Trace contaminants are controlled and monitored in the habitable environment. Short term maximum allowable concentrations, and continuous maximum allowable concentrations are specified. These requirements and the failure tolerance and safe haven requirements determine the trace contaminant control performance requirements for the various configurations and build-up scenario.

A system model similar to the intermodule ventilation model should be developed to assess the trace contaminant control system performance under various conditions. It may be desirable to add a transient capability to the model to evaluate recovery times for various failure scenarios. This capability would allow evaluation of the best distribution of control and monitoring equipment for each configuration and failure scenario. Study objectives would be to determine safe haven configurations for failure scenarios, and optimum locations of control and monitoring equipment to meet safe haven and build up scenarios.

Water Storage Processing and Distribution (Including Urine Collection Processing and Storage)

Failure tolerance requirements must be met for potable and hygiene water during space station configuration evolution. The system must also accommodate safe haven requirements. In the event a pressurized module is functionally lost due to removal or failure, the water distribution system must have redundant paths to provide resources to the remaining habitable volumes. The removal or loss of a module may involve water loss, and loss of water processing storage and recovery capability. The impacts of this loss can be assessed for each failure scenario, and/or configuration change.

The objectives of this study would be to determine the adequacy of the water distribution system to by pass disabled modules, and to provide sufficient reserve capability to accommodate water losses that could be associated with module losses. The study should also identify safe haven configurations for selected failure scenarios for each of the growth configurations.

Fecal Waste Collection

Each of the growth configuration failure scenarios involving the loss of pressurized modules will require identification of a safe haven configuration. The safe haven configuration should contain a fecal waste collection capability to support the entire crew. Assessments should be made to identify adequate distribution of fecal waste collection systems to assure that safe haven requirements are satisfied.

Food Storage

Safe haven provision requirements require food and equipment to be available in the remaining pressurized volume for a period of 22 days (SP 30000 Revision K), or 45 days (CR to Revision K).

An assessment to determine food and equipment distribution for each growth configuration should be made to assure these requirements are satisfied.

System Study

Shown in Exhibit 2.6.2-3 is a summary of study recommendations. The results from evaluating each subsystem should be combined with other requirements, such as access to escape vehicles, recovery of EVA personnel etc., to define a safe haven configuration for each of the growth station configurations. Although intermodule ventilation analysis was not performed under this task, the air distribution system characteristics and capabilities should be included in the overall system assessments to identify safe haven configurations and in investigating the buildup scenarios.

**Volume III - Appendix F
Task 6 Report
ECLSS Evolution: "Hooks and Scars" Study and Cost/Benefit Analysis**

Technical Report

September 3, 1991

ADVANCED LIFE SUPPORT ANALYSES (Contract No.: NAS8-38781)

APPROVED BY: Jay M. Laue
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Task 6 - ECLSS Evolution: "Hooks and Scars" Study and Cost/Benefit Analysis

The purpose of task 6 was to identify the rack level interface requirements of the alternative technologies evaluated in Task 1 and compare these with the rack level interfaces for racks with the baseline technologies. Those technologies which require rack level interfaces not required by the baseline technologies were to be identified and the additional interfaces required were to be defined. Furthermore, the cost of implementing the identified "hooks and scars" including the costs of tubing, ducting, wiring, power, etc. were to be evaluated and compared with the benefits of reduced resupply, increased capabilities, simplified operation, reduced maintenance needs, etc. This effort is dependant on the availability of the results of the SSF restructuring activity to provide information on the baseline locations of ECLS subsystems, the interfaces provided, and the scars provided to accommodate EMCC.

The purpose of this task was to identify the rack-level interface requirements of the alternative technologies evaluated in Task 2 and compare these with the rack-level interfaces requirements for the baseline technologies. This involved identifying those technologies which require rack-level interfaces not required by the baseline technologies and defining the additional interfaces required. This effort was dependent on the availability of the results of the Space Station Freedom restructuring activity to provide information on the baseline locations of ECLSS subsystems, the interfaces provided, and the scars provided to accommodate the EMCC configuration. The analysis performed under this task was focused on a specific Atmosphere Revitalization (AR) subsystem, O₂ Generation, in order to identify the rack-level interface "hooks and scars" requirements for the replacement of the EMCC baseline SFWE technology with the SPE technology.

In order to perform a comparative evaluation of the alternative ECLSS technologies rack-level requirements with the baseline technologies requirements, the baseline technologies were identified and are listed in Exhibit F-1. Based on the information gathered, the technologies represented in the Technology Interface Database (developed in Task 2), and given baseline technologies, the comparative analysis was conducted on the O₂ Generation AR subsystem. These O₂ generation subsystems include the baseline technology, Static Feed Water Electrolysis (SFWE), and an alternative replacement technology, Solid Polymer Electrolysis (SPE).

ECLSS Subsystem Category	Baseline Technology
CO2 Removal	4-Bed Molecular Mole Sieve (4BMS)
CO2 Reduction	Sabatier
O2 Generation	Static Feed Water Electrolysis (SFWE)
Urine Recovery	Vapor Compression Distillation (VCD)
Water Processing	Multifiltration (MF)

Exhibit F-1. ECLSS Baseline Technologies for the EMCC Configuration

The rack-level interface requirements were identified for the SFWE and SPE ECLSS technologies from information found in the Interface Technologies Database and the ECLSS Technology Demonstrator Program (TDP) documentation. Exhibit F-2 summarizes the basic rack-level requirements for the fluid and electrical interfaces, respectively, and presents a comparison between the related interface for each technology. The information shown in this exhibit provides a good understanding of the interface commonalities of these two ECLSS technologies.

In reference to the information shown in Exhibit F-2, the number of required "hooks and scars" and interface issues were considered minimal due to the interface compatibilities between baseline and the alternate technology. In fact, the types and number of SFWE and SPE fluid interface input and outputs are the same, with the exception of additional liquid coolant and primary power connections required by the SFWE system. As shown in this exhibit, almost all of the fluid interface connections are identical, with the exception of some of the operation requirement for the lines and connectors. These exceptions can be planned for in the ECLSS evolution by selection of lines and connectors with operational parameters high enough to meet both technologies interface requirements. Electrical interface requirements for both SFWE and SPE technologies can be met by designing the electrical rack-level interfaces to meet the maximum power distribution requirements of both technologies. Due to the commonalities between the electrical input configuration of the two systems, this would require retaining the RS232C cables, and replacement and removal some of the DC power cables when the SFWE technology is replaced with the SPE technology.

ELECTRICAL INTERFACES		TECHNOLOGY			
		SFWE (Baseline)		SPE (Candidate Replacement)	
		Requirement	Connector	Requirement	Connector
Primary Power		28 VDC (30A)	TBD	28 VDC	MS27497E12F4PN (Plug)
Primary 60Hz Power		115 VAC (60Hz, 1Ø, 10A)	TBD	115 VAC (60Hz, 3Ø)	MS27497E14F5PN (Plug)
Primary 400Hz Power		115/208 VAC (400Hz, 3Ø, 25A)	TBD		
CCDS Communication		RS232C Protocol	TBD	RS232C Protocol	MS27497E10F35SN (Socket)

FLUID INTERFACES (Liquid & Gas)		PRESSURE (psia)		TEMPERATURE		FLOW (lb/day)		Fitting Type	Fitting Size (in.)
		Nominal	Range	Nominal	Range	Nominal	Range		
INPUTS	H ₂ O Feed	32	30-35	70	60-80	12.78		O-Ring Seal	1/4
		35	35-40	Ambient	60-120	12.48	216-16.56	Compression	1/4
	N ₂ Supply (O ₂ Side)	182	180-185	70	60-80	0.076	0.076	O-Ring Seal	1/4
	(H ₂ Side)	182	180-185	70	60-80	included †	included †	O-Ring Seal	1/4
OUTPUTS	(O ₂ & H ₂)	265	260-270	Ambient	Ambient-100	* 67 in ³	* 67 in ³	Compression	1/4
	O ₂ Product	20	14.5-25	70	60-85	11.12		O-Ring Seal	1/4
		20	Ambient-230	120	Ambient-130	11.04	192-14.64	O-Ring Seal	1/2
	H ₂ Product	20	14.5-25	70	60-85	1.39		O-Ring Seal	1/4
		25	Ambient-195	120	Ambient-130	1.39	024-1.85	O-Ring Seal	1/4
	O ₂ Vent	14.7	0-20	80	70-95			O-Ring Seal	1/4
		Ambient	Ambient-230	120	Ambient-130	* 8.5 in ³	* 8.5 in ³	O-Ring Seal	1/2
	H ₂ Vent	14.7	0-20	80	70-95			O-Ring Seal	1/4
		Ambient	Ambient-195	120	Ambient-130	* 73 in ³	* 73 in ³	O-Ring Seal	1/4
	Liquid Coolant	25	14.5-30	44	42-46	12k	9.6k-14.4k		

* @ Start-Up

☐ BASELINE TECHNOLOGY
 Static Feed Water Electrolysis (SFWE)

☐ CANDIDATE REPLACEMENT TECHNOLOGY
 Solid Polymer Electrolysis (SPE)

Exhibit F-2. Comparison of Fluid and Electrical Interfaces for SFWE and SPE Technologies

In order to reduce the required number of "hooks and scars", the temperature and pressure requirements for each fluid interface should exceed the highest value of the two technologies by a predefined safety factor. The initial designed input pressure for the H₂O and N₂ supply should be based on the higher SPE technology requirements and then regulated down to the required pressure for the baseline SFWE technology. This will provide for easier deregulation on the supply pressures and connection of the interfaces between the baseline and replacement technologies. The SFWE technology requires two N₂ supply lines, one for the O₂ side and the other for the H₂ side,

while the SPE technology requires only one N₂ supply line. This would require that one of the N₂ supply lines be plugged when the SFWE is replaced by the SPE. Also, the H₂O and N₂ system interface connector types are different and require either a transition connector be used between the rack interface line and the SPE system or that the rack interface line be replaced with a line containing a 1/4" compression fitting at one end, instead of the 1/4" o-ring seal fitting used with the SFWE system. Considerations should be given to the 1/2" O₂ product and vent lines and connectors to determine if 1/4" lines and connectors could be utilized, providing a small reduction in the "hooks and scars" requirements. The liquid coolant interfaces required for the SFWE system is not required for the SPE system and should be removed, due to the fact that the SPE system utilizes cabin air, which is blown through the system to dissipate heat generated by the system, and requires no interfaces.

As mentioned above, the electrical interface requirements for both SFWE and SPE technologies can be met by designing the electrical rack-level interfaces to meet the maximum power distribution requirements of both technologies. The types of electrical interface connectors were not specified for the SFWE system and, therefore, could use the same type of interface connectors used by the SPE system. This can be accomplished by using the same connectors but with only the required pin configuration for each electrical interface for the given technology. Both technologies require basically the same primary 28 VDC interfaces. The 115 VAC power requirements will be changed to 28 VDC for the final flight version of each technology. When the SFWE system is replaced with the SPE system, a DC power cable should be removed and its connectors, on the rack interface plate, should be plugged to guard against any shorting. The SFWE system's RS232C rack interface connection requires only three of the normal RS232 data lines, where the SPE system requires seven of the data lines for Command, Control, and Display Subsystem (CCDS). Since both technologies use the same data line configuration, RS232C protocol, the same cable can be used for CCDS communications for both technology systems.

In addition to these "hooks and scars" issues, a related issue is the heat load penalties for both technologies on the Space Station. The SFWE system dissipates 648 BTU/HR to the cabin air heat exchanger and 737 BTU/HR to the station's cold plate heat exchanger, while the SPE system dissipates 1307 BTU/HR from the electrolysis assembly and 3901 BTU/HR from the electrolysis cell stack DC power to the cabin air heat exchanger. The SPE technology shows definite heat load penalties placed on the Space Station.

The EMCC AR baseline technology for O₂ generation, SFWE, and one of its alternative replacement technologies, SPE, was found to provide many interchangeable fluid and electrical rack-level interface, due to the related technologies interface commonalties. With a minimal number of rack-level "hooks and scars" identified, the SFWE technology could be replaced with the SPE technology. A summary of the rack-level interface "hooks and scars" for the replacement

of the SFWE technology with the SPE technology is shown in Exhibit F-3. In addition, one issue that should be considered is the heat load penalty placed on the Space Station by this ECLSS technology evolution.

- Provide a 1/2" to 1/4" Reduction Line for the O2 Product and Vent Outputs
- Provide an O-Ring Fitting to Compression Fitting Transition line for H2O and N2 Supply Rack Interfaces for the SPE Technology
- All Fluid Interface Lines and Connectors Should Accommodate the Higher Operational Pressure and Temperature Requirements of the SPE Technology.
- Provide Plugs for the Rack Interface Connector for the DC Power Sources and Liquid Coolant sources
- Remove DC power cables and Liquid Coolant lines that are not needed
- Provide a Complete RS232 Rack Connection and Cable Configuration

Exhibit F-3. Rack-Level Interface "Hooks and Scars" Summary for Replacement of SFWE Technology with SPE Technology

The work accomplished under this task included limited analyses which were performed comparing the Solid Polymer Electrolysis O2 generation subsystem with the baseline Static Feed Water Electrolysis Subsystem. The results are examples of the types of "hooks and scars" required to accommodate the alternative technologies. For some alternative technologies relatively minor accommodations will allow the flexibility to incorporate them. Additional data on the other technologies is scarce and more time is required to gather this data. The procedures for performing a cost/benefit analysis has been developed but no results are available. This analysis depends on additional data on the technologies which is scarce and more time is required to gather this data. Appendix F is a full report of the work done under this task.